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Monterey, California: U.S. Naval Postgraduate School

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AN X-RAY METHOD FOR FOLLOWING
THE PRECIPITATION PROCESS IN
POLYCRYSTALLINE ALUMINUM-COPPER

JOHN T. LARSEN

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John T. Larsen

AN X-RAY METHOD FOR FOLLOWING THE
PRECIPITATION PROCESS
IN POLYCRYSTALLINE ALUMINUM-COPPER

by

John T. Larsen

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
MATERIAL SCIENCE

United States Naval Postgraduate School
Monterey, California

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ARSEN, J.

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This work is accepted as fulfilling
the thesis requirements for the degree of

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IN

MATERIAL SCIENCE

from the

United States Naval Postgraduate School

ABSTRACT

An experimental study has been made of the feasibility of following the precipitation process in a polycrystalline aluminum-2½% copper alloy. The intermediate structures formed during ageing have previously been determined by single crystal methods to pass through the following sequence:



The sequence of structures was followed by analysis of the diffractometer line profile of the $\alpha(200)$ peaks. The experimental profiles were corrected for instrumental broadening by the Stokes method. One-dimensional Patterson projections of the electron density distribution in the alloys were synthesized from the corrected profiles.

The complete sequence of intermediate precipitates could not be realized in this investigation. However it was possible by this method to distinguish between the G.P. [1] and θ' structures by observing the height and shift of the Patterson function origin peaks.

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The writer is indebted to Professor John R. Clark, Department of Material Science and Chemistry, for his guidance and encouragement given during the course of this investigation.

1. Introduction.

The phenomenon of precipitation hardening holds great commercial interest. It is a method of enhancing the mechanical properties of a metal without resorting to other processes such as work hardening, dispersion hardening or a martensitic type transformation. It eliminates the concern regarding the hardenability of a metal. Metal parts may also be formed or fabricated in a soft condition and then hardened by a relatively simple ageing treatment while retaining excellent dimensional stability. One example of the importance of precipitation hardening is its application to aluminum alloys which has resulted in a great number of usable high strength materials.

The mechanism of precipitation hardening is not at all simple. The most basic concept involves the formation of a stable phase dispersed throughout a matrix. This does not include dispersion hardening, which is due to the presence of a second phase dispersed in the matrix. However, it is not a precipitation process. Even in the basic concept of precipitation there are constraints imposed on the nucleation and growth of such a phase because it is being formed in a solid solution. In general, the process is much more complicated than this. It varies with each alloy system but usually involves the precipitation of a metastable phase, which later gives way to a stable one. There may be as many as three intermediate stages before the stable precipitate is formed. The intermediates may or may not be true phases, depending on the alloy system.

The intermediate stages hold great interest. In many alloy systems these intermediates have the greatest influence on mechanical properties, and the formation of a stable precipitate results in a

decrease in hardness and strength.

The Al-Cu alloy represents an ideal system in which to study the age-hardening process. It is representative of many systems for it displays both substitutional and displacement disorder during ageing. The copper atoms have a greater scattering factor and a smaller radius than the aluminum atoms ($f_{Cu}/f_{Al} = 29/13$ and 2.56 \AA compared to 2.86 \AA). The difference in atomic size results in the displacement disorder while the greater scattering factor of copper allows its effects to be detected by x-ray analysis.

The age-hardening system in Al-Cu has been studied more than any other. As a result its sequence of structures is known in considerable detail.¹

The mechanism of the decomposition of the quenched supersaturated solid solution shows four different stages whose relative roles depend strongly on the annealing temperature. In general the sequence may be represented as follows:



Two stages, θ and θ' , correspond to true precipitates of composition CuAl_2 , where θ is the equilibrium phase. The G.P. refers to a "Guinier-Preston zone", which may be defined as a region rich in solute atoms which is formed on certain planes in the solvent matrix and retains what is essentially the structure of the matrix. G.P.[1] is a copper rich region of plate-like shape formed on $\{100\}$ planes of the aluminum matrix whose maximum size is a few atomic planes thick and up to about 100 \AA in diameter. G.P.[2] displays features

¹J. M. Silcock, T. J. Heal and H. K. Hardy, J. Inst. Metals 82, 240-242 (1953).

of a zone and a true phase. As these platelets reach a thickness of about 30 \AA they become unstable and dissolve. They may be considered as having a lattice similar to that of the aluminum matrix. To a first approximation it is merely a superlattice of aluminum, tetragonal with $c/a = 2$ where a is the parameter of aluminum.

The above structures do not necessarily evolve from one another in sequence, but two (or more) may occur simultaneously in the same specimen. The conditions have been determined in which the three metastable phases and the equilibrium phase appear as a function of time and temperature for different concentrations of Cu in Al.²

A variety of x-ray techniques have been used in the numerous precipitation investigations. Single crystals have generally been employed using both white and monochromatic radiation. Some work has been done using normal powder methods. The small angle scatter method has been applied with great success by Guinier.³ The techniques using single crystals and monochromatic radiation have advantages of ease and certainty of interpretation in terms of a reciprocal lattice plot, but require sophisticated equipment and precise experimental technique. Some of the results obtained by the above methods have recently been confirmed by electron microscopic photographs.⁴ The use of an x-ray diffractometer in the analysis of polycrystalline specimens is attractive because of the relatively simple procedures involved and the possible extension of

²Ibid., pp. 243-45.

³A. Guinier, Ann. Phys. 12, 161 (1939).

⁴G. Thomas, Transmission Electron Microscopy of Metals, pp. 236-248.

the technique to precipitation studies in commercial alloys. Hence, it is the purpose of this investigation to follow the ageing process in a polycrystalline Al-4%Cu alloy by means of a diffraction line shape analysis and Patterson projection of the electron density distribution within the alloy.

The data necessary to form a Patterson function is available from a diffraction line profile, as is shown below. However, a true line profile must first be obtained by correcting the observed profile for instrumental broadening, due mainly to the slight spread of wavelengths in the incident radiation. A method has been derived by Stokes using the convolution theorem of mathematics to correct the experimental line shape without any prior assumptions concerning the corrected line shape.⁵ The method consists essentially of obtaining the Fourier coefficients for the broadened and reference curves, operating on these coefficients (termed unfolding), and then synthesizing the corrected curve from the unfolded coefficients. This technique eliminated broadening due to $K\alpha$ doubling as well as other forms of broadening.

It has been shown that the true line profile is proportional to the Fourier transform of the square of the absolute magnitude of the structure factor, $|F_{hkl}|^2$.⁶ The structure factor F_{hkl} , in general a complex quantity, represents something real about a crystalline material for it is the Fourier transform of the electron density in

⁵A. R. Stokes, Proc. Phys. Soc. London 61, 382 (1948).

⁶A. J. C. Wilson, X-Ray Optics, p. 107.

the material.⁷ Experimentally only $|F_{hkl}|^2$ is determined which yields no information concerning its phase. If the phase relations could be determined experimentally there would be no problem in finding the arrangement of atoms in any crystal, no matter how complicated. Of the methods proposed to circumvent the phase problem, the Patterson function has emerged as the most powerful and adaptable. This function is a Fourier series whose coefficients are $|F_{hkl}|^2$.⁸ If one considers the Fourier coefficients $|F_{hkl}|^2$ as derived by forming products of each Fourier coefficient F_{hkl} with its complex conjugate, the electron density function can be derived directly from the Patterson function. The Patterson function is essentially a display of all the vector lengths between atoms of a unit cell. All the vectors of one length will then appear as a peak in this display. Since the reverse vectors are also displayed, it is necessary to sort out the duplicated peaks in order to arrive at the electron density function.

2. Alloy preparation.

The Al-4%Cu (by weight) alloy was prepared using 99.99% ingot Al and 99.94% Cu shot. The aluminum was first melted in an induction heated graphite crucible, and then the copper shot was added. The molten metal was held between 700° and 720°C for 45 minutes to ensure complete solution of the copper. The alloy was cast into a flat rectangular zirconia boat, preheated to 700°C, and allowed to solidify at room temperature. The ingot thus formed weighed 125 grams,

⁷A. Guinier, X-Ray Diffraction, p. 92.

⁸M. J. Buerger, Vector Space, pp. 5-10.

measuring approximately 4" x 2 $\frac{1}{4}$ " x $\frac{3}{8}$ ".

Microscopic examination of the ingot revealed a large grained structure containing intergranular theta phase and no evidence of undissolved copper.

The ingot was homogenized at 542°C for 24 hours and furnace cooled. Grain refinement was accomplished by cold rolling and recrystallizing at 600°C for one hour. The amount of reduction per pass through the rolls was limited to about 20% due to work hardening, so the refinement treatment had to be repeated three times, resulting in an ingot .17" thick, and containing equiaxed small grains with finely divided theta phase dispersed throughout.

Eight hardness specimens were cut from the ingot, each being about 1.75" x .5" x .17" in size. A hole was drilled in one corner of each specimen and top and bottom surfaces were smoothed on no. 0 and no. 3/0 metallographic paper.

3. Solution treatment and age hardening.

The eight specimens were strung on a wire with a $\frac{1}{2}$ " separation to ensure rapid heat transfer both on heating and quenching. They were solution treated in a salt bath for six days at 536°C, which is about 36° above the solid solubility of 4% copper in aluminum.⁹ Following the solution treatment the specimens were quenched in room temperature water, and the as quenched hardness was taken immediately on one specimen. The surface irregularities caused by the salt bath on the remaining specimens were removed by lightly

⁹M. Hansen, Constitution of Binary Alloys, p. 84.

polishing on no. 0 and no. 3/0 paper. They were then suspended in an oil bath at 165°C for ageing. The as quenched hardness specimen was aged at room temperature.

Microscopic examination of the as quenched hardness specimen following solution treatment revealed a small amount of undissolved theta phase in the structure. A lattice parameter measurement on the α (422) diffraction peak of this specimen indicated that about 2½% of the copper had gone into solution. The small amount of undissolved theta would have no effect other than to reduce the peak hardness obtained during ageing.

4. Diffraction procedure.

As each specimen reached its respective ageing time, it was quenched in room temperature water and hardness readings were taken immediately. No less than six readings were taken on both sides to ensure a good average. The surfaces were then given a rough electro-polish to remove the oxide layer and to ensure that the surface was as nearly a true representation of the bulk of the specimen as possible. Chemical macro-etching was not used due to its preferential removal of copper from the alloy.

The α (200) peak of each specimen was recorded using a Norelco x-ray diffractometer with Ni filtered $\text{CuK}\alpha$ radiation. The diffracted radiation was counted by a xenon proportional tube in conjunction with a pulse height analyzer set to pass the central 90% of the pulse distribution.

The reference peak for the Stokes' unfolding was obtained from a recrystallized specimen of the pure ingot aluminum. It was possible

to get a well resolved $K\alpha$ doublet for the (200) peak from this specimen.

5. Treatment of data.

The intensity of each diffraction peak was recorded as a function of 2θ . Due to the sharpness of the reference peak it was necessary to use an interval of $.0125^\circ 2\theta$ between points to describe the peak by a smooth curve. It was possible to use a point interval of $.025^\circ 2\theta$ to describe the broadened peaks. A total interval of 1.8° was used on all broadened peaks except the as quenched and aged one day specimens, where it was possible to use slightly shorter intervals due to their narrowness. The maximum value of the diffraction peak was centered in the total interval in all cases.

The unfolding and Patterson function synthesis calculations were performed by the U. S. Naval Postgraduate School's CDC 1604 electronic computer. The diffraction intensity data was punched onto computer cards for input to a Fortran program developed by Prof. J. R. Clark, Dept. of Material Science and Chemistry, to execute the above calculations.

6. Experimental results.

The hardness/ageing time curve for the specimens aged at 165°C is shown in Fig. 1, page 9. The specimen aged at room temperature for 65 days attained a Rockwell "F" hardness of 77.4.

The lattice parameter of the as quenched specimen was 4.044\AA , which corresponds to $2\frac{1}{2}$ weight per cent copper in solution. The specimen aged at 165°C for one and two days retained this same lattice parameter. The lattice parameter of the specimens aged for five days

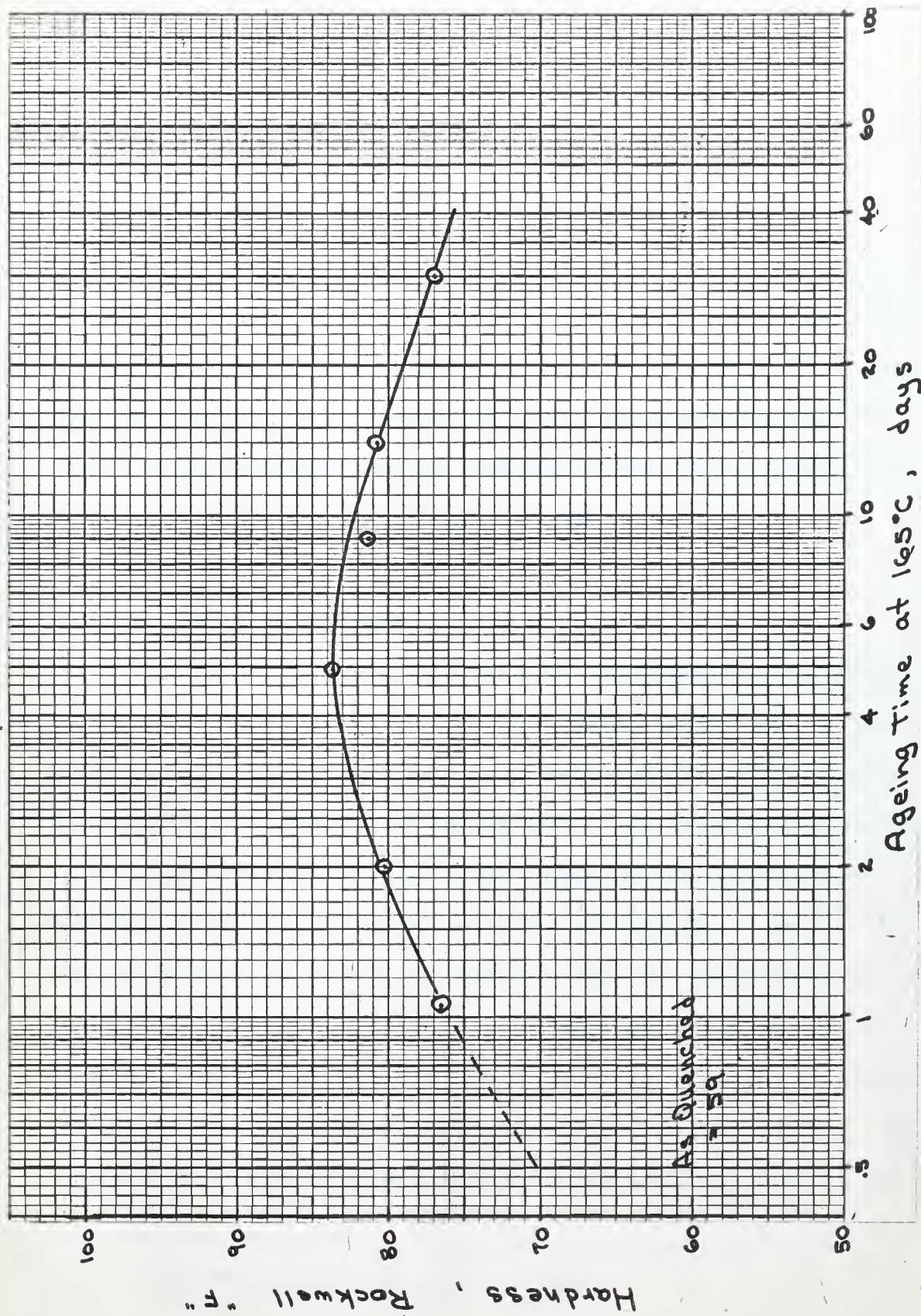


Fig. 1. Hardness/Ageing Time Curve

and longer was 4.049\AA , which is the same as that of pure aluminum. The as quenched specimen retained the same lattice parameter on ageing at room temperature for 65 days.

The Patterson functions for the artificially and naturally aged specimens are shown in Appendix I on both a small and large scale. The ordinate is $P(\vec{w})$, where \vec{w} is the interatomic vector length. The vector between any two atoms in the crystal always has its tail at the origin in the Patterson function. The abscissa then represents the magnitude of \vec{w} as it ranges from zero to "a", the lattice parameter of aluminum, in increments of $.01a$. The Patterson functions displayed in Appendix I are the one-dimensional projections of the electron density in the $\langle 100 \rangle_{Al}$ direction.

7. Discussion of results.

The lattice parameter and hardness measurements were used to confirm the structures present at each ageing time. The lattice parameters were determined with only sufficient precision to detect any changes as a function of ageing time. The structures contained in each specimen were determined by comparing the experimental hardness curve with the hardness curves of Silcock, et al.¹⁰ It was not possible to obtain the complete sequence of intermediate precipitates on ageing at 165°C since only $2\frac{1}{2}\%$ copper went into solution. Initial ageing at 165°C produces G.P.[2] and Θ' simultaneously, while at peak hardness (five days) Θ' predominates. The specimen fully aged at room temperature contains only G.P.[1] since

¹⁰ Silcock, et al., op. cit., p. 243.

the precipitation process does not progress beyond this point in naturally aged specimens.¹¹

Lattice parameter measurements confirmed that the above structures were present. A constant value of parameter is characteristic of the G.P. zones.¹² It was observed that the parameter remained constant during natural ageing. The parameter also remained constant through two days ageing at 165°C, indicating that G. P.[2] was present during this time. At five days ageing the parameter had relaxed to the pure aluminum value. Hence θ' became the predominant intermediate at this time.

When comparing the Patterson origin peaks, Appendix I, Figs. 4 through 11, it is observed that the as quenched and naturally aged specimens have peaks exactly at the origin while those of the artificially aged specimens are shifted slightly. Also the origin peak for the naturally aged specimen is roughly twice the magnitude of all the others. It has been shown that the Patterson peak height is not a true measure of the product of the number of electrons, $Z_1 Z_2$, contained in the two atoms separated by the vector that corresponds to the peak.¹³ The peak height is directly proportional to $Z_1 Z_2$ but inversely proportional to the sum of the cross-sections of the electron density peaks for a one-dimensional Patterson peak. Therefore a high Patterson peak is not necessarily due to two heavy atoms. The height also depends on the product of the electron

¹¹Ibid.

¹²A. Guinier, Solid State Physics, Vol. 9, p. 341.

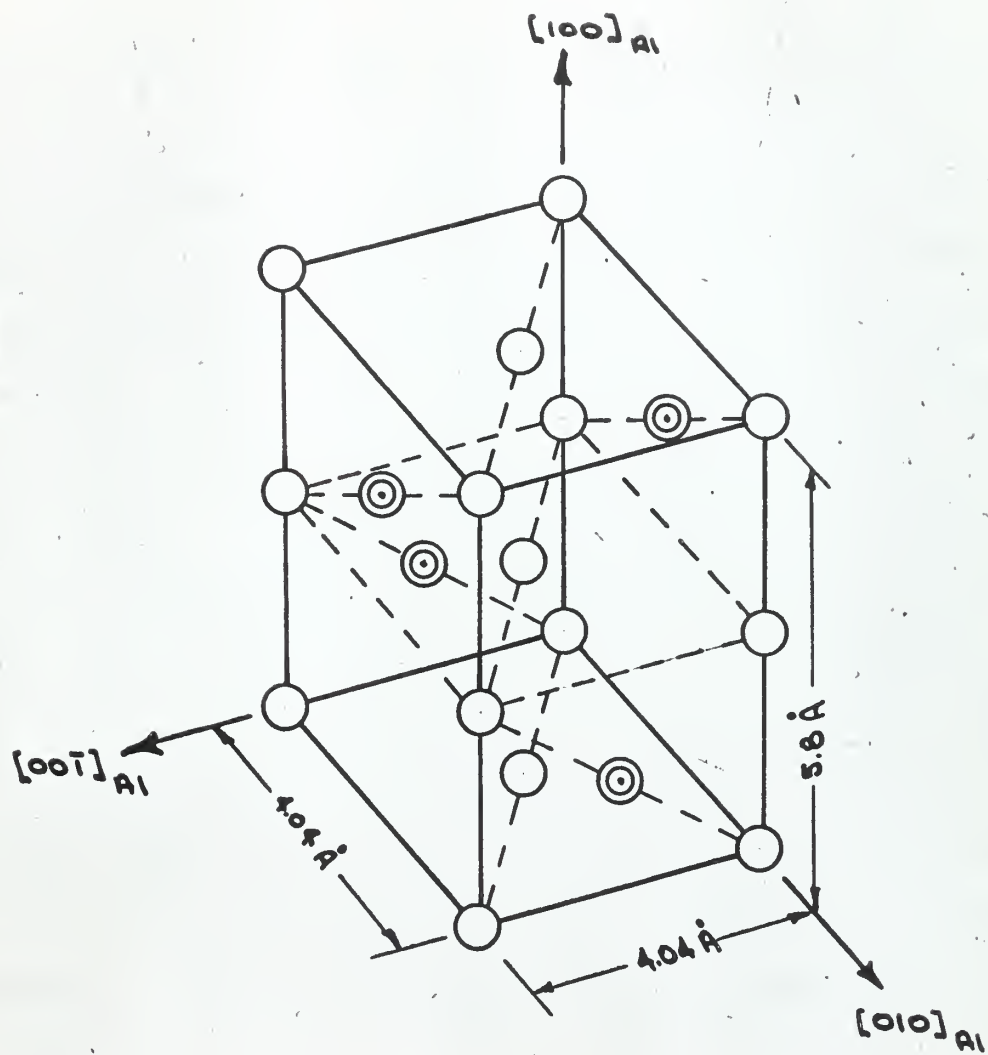
¹³Buerger, op. cit., p. 26.

densities of the atoms in the pair.

The copper atom has a greater electron density than aluminum. Copper contains 29 electrons compared to 13 in aluminum and is 11% smaller in atomic size. Hence the presence of copper in an atom pair would substantially increase the Patterson peak height for that pair. In a specimen fully aged at room temperature a large fraction of the copper atoms are assembled in the G.P. zones, which are a few atomic layers thick and are on the average less than 100\AA apart.¹⁴ When looking perpendicular to the zones in the $\langle 100 \rangle_{Al}$ direction there would be a certain number of vectors of length "a" between atom pairs containing one or two copper atoms. There would be a smaller number of like vectors in the as quenched specimen, which is assumed to be a random substitutional solid solution of copper atoms in the aluminum matrix. The number of such vectors would also be less in the artificially aged specimens, which initially contained G.P.[2] and Θ' and later only Θ' . This can best be shown by considering the accepted structure of Θ' , Fig. 2, page 13. The Θ' structure is tetragonal with parameters $a = 4.04\text{\AA}$ and $c = 5.8\text{\AA}$, and the axes are parallel to the $\langle 100 \rangle_{Al}$ directions.¹⁵ Only one of the three possible orientations of Θ' is shown in Fig. 2. When all three orientations are considered together, only two produce copper atom separations of 4.04\AA in the $\langle 100 \rangle_{Al}$ direction. Where G.P.[2] and Θ' occur together the copper atoms are shared between them and the total number available to share in atom pairs 4.04\AA apart is less

¹⁴A. Guinier, Solid State Physics, p. 341.

¹⁵Silcock, et al., op cit., p. 242



○ Al atoms

⊙ Cu atoms

Fig. 2. Structure of θ'

than in the naturally aged specimen. This is also true when only Θ' is present. Hence one would expect G.P.[1] zones to produce higher Patterson origin peaks than the other intermediate structures.

As seen in Appendix I the left origin Patterson peaks occur at \vec{w} values slightly less than "a" for all artificially aged specimens. This shift is real and is not due to an error in calculation or plotting of the Patterson function. The peak is at .98a for one days ageing and at .99a for longer ageing times. This is best explained by considering the matrix distortion due to each of the intermediate precipitates. When a copper atom is substituted for an aluminum atom the matrix lattice contracts locally due to the smaller atomic size of copper. All three intermediate precipitates are coherent with the aluminum matrix. This coherency between matrix and precipitate lattices produces distortions in the matrix removed from the precipitate interface. The extent of the matrix distortion depends on the size and shape of the precipitate particle. Thus when G.P.[1] zones are formed in their thin disc shape the lattice distortions are small and do not extend far from the interface. The average cell parameter is then that of the matrix and the Patterson peak remains at $|\vec{w}| = a$.

When G.P.[2] is present the lattice distortions are more extensive than those due to G.P.[1], since the G.P.[2] zones are thicker and have larger diameters. The distortions due to Θ' are also extensive because of the Θ' c parameter of 5.8Å. Thus when G.P.[2] and Θ' are present together after ageing one day the lattice is distorted by their combined effects and the Patterson peak occurs at $|\vec{w}| = .98a$. As the G.P.[2] zones dissolve and Θ' grows with longer ageing times the

lattice distortion decreases and is due to Θ' alone at peak hardness of five days.

In Appendix I, Figs. 12 through 19, are shown the Patterson functions on a large scale. In general, the number of resolved peaks increases as the ageing time increases. This is due to the increasing number of harmonics used in the synthesis of the Patterson function. The number of harmonics used in each case is determined by the point at which the coefficients of the broadened curve have decreased to a small value and those of the reference curve still have an appreciable value. The use of higher harmonics beyond this point results in a greater uncertainty in the coefficients of the corrected curve.¹⁶ The intermediate peaks in the above Patterson functions are all quite small compared to the origin peaks. The resolution presented by the intermediate peaks is considerably greater than the 1.5 to 2 Å expected using x-radiation of 1.542 Å wave length. Thus the fine detail is false and is only a result of the harmonic analysis. No information concerning atomic positions can be gained from it. It is observed that the fine details of the Patterson functions for five days ageing and longer are essentially the same indicating that the line profiles are very nearly the same.

8. Conclusions and recommendations.

The scattered intensity distribution in reciprocal space for the aluminum-copper alloy is shown in Fig. 3.¹⁷ The scattering

¹⁶Stokes, op. cit., p. 389.

¹⁷A. Guinier, Solid State Physics, p. 339.



streaks around the nodes of the reciprocal lattice are due to the destruction of the strictly periodic electron density distribution in the crystal. This destruction is caused by the G. P. zones.

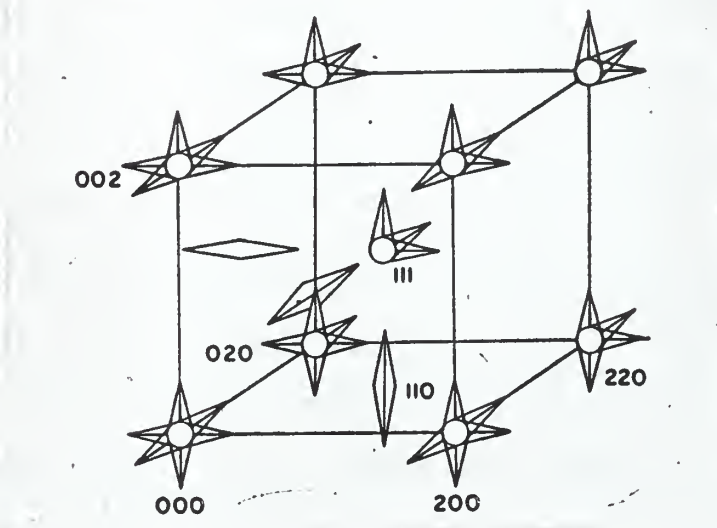


Fig. 3. Scattering in the reciprocal space of Al-Cu.

The streaks pass precisely through the nodes of the matrix and along the $\langle 100 \rangle$ rows of the reciprocal lattice. The fact that the G.P. zones distort the matrix lattice causes the scattering streaks to appear only on the high-angle side of the reciprocal lattice nodes.

It was anticipated that the diffuse streaks about the nodes would contribute to the diffraction process in a distinctive way. It should be possible to differentiate G.P.[1] from G.P.[2] since the length of the diffuse streaks are related to the size of the zone. This distinction could not be realized in the present investigation as G.P.[2] zones were not obtained by themselves on ageing. However

it was possible to distinguish G.P.[1] from Θ' by observing the height and shift of the Patterson origin peak.

The amount contributed to the diffraction profile by the diffuse scattering streaks is uncertain. It is possible that the broadening of the profile due to instrumental factors, which were corrected for, is greater than that resulting from the diffuse streaks. However, since the instrumental broadening remains constant with ageing the profile changes due to the diffuse scattering streaks could be detectable. The thermal vibrations of the atoms about their average position in the crystal also produce anisotropic diffuse diffraction effects about the nodes of the reciprocal lattice. The thermal diffuse scattering is related to the elastic properties of the crystal, which certainly change during ageing. Hence, the changes in thermal scattering should also contribute to the line profile changes during ageing. The amount contributed and the best means of detecting it is a difficult problem to analyze quantitatively. There has been no attempt in this investigation to do so.

There are several ways in which the application of this method of analysis could be improved. The use of monochromatic x-rays would eliminate the profile broadening due to the spectral spread of the incident beam. In order to observe the effect of each intermediate precipitate on the line profile it is necessary to have them existing separately in the alloy. The transition in the aluminum-copper system from G.P.[1] \rightarrow G.P.[2] could best be observed by ageing a 4% copper alloy at 110°C, and from G.P.[2] \rightarrow Θ' by ageing the same alloy at 190°C. The complete intermediate sequence could be achieved with definite separations in structures by ageing a 4.5% copper alloy at 130°C but would require ageing times of about 400 days.



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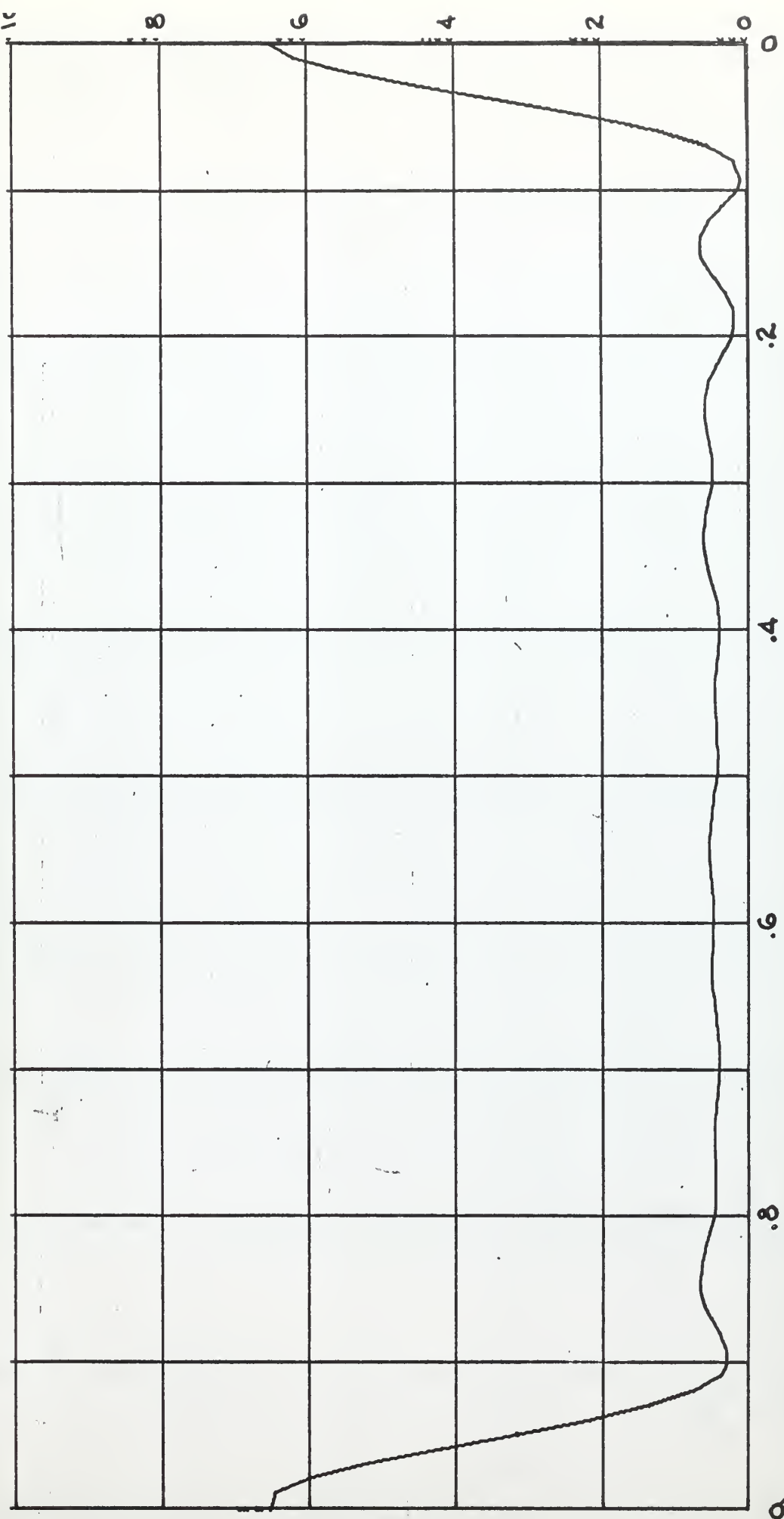
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APPENDIX I

PATTERSON PROJECTIONS

The Patterson functions for the naturally and artificially aged specimens are shown on a small scale in Figs. 4 through 11, and on a large scale in Figs. 12 through 19. The ordinate is $P(\vec{w})$, where \vec{w} is the interatomic vector. The abscissa represents the magnitude of \vec{w} as it ranges from 0 to "a".





13

FIGURE 4. Patterson Function, As quenched specimen



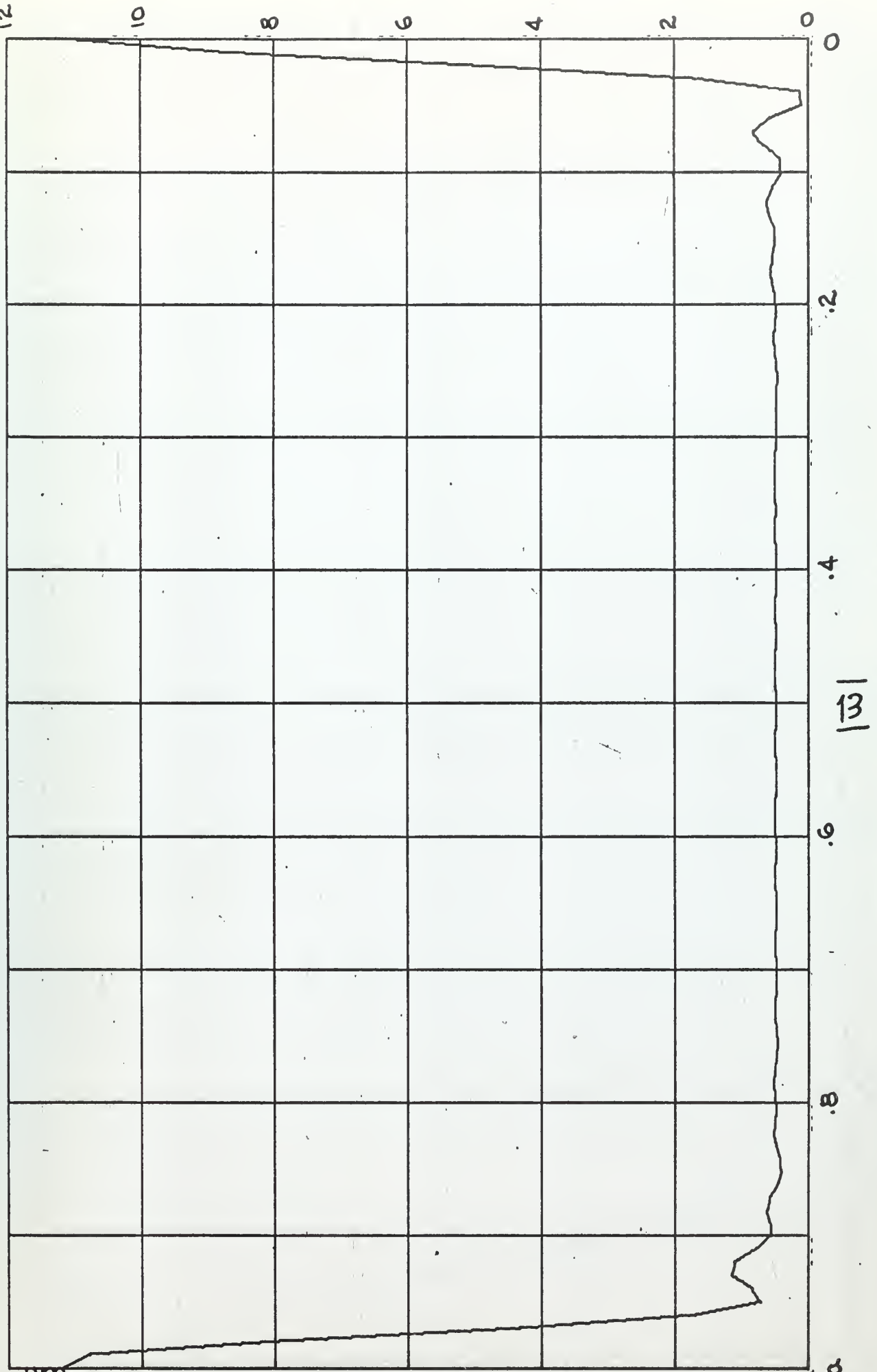


FIGURE 5. Patterson Function, aged 65 days at room temperature



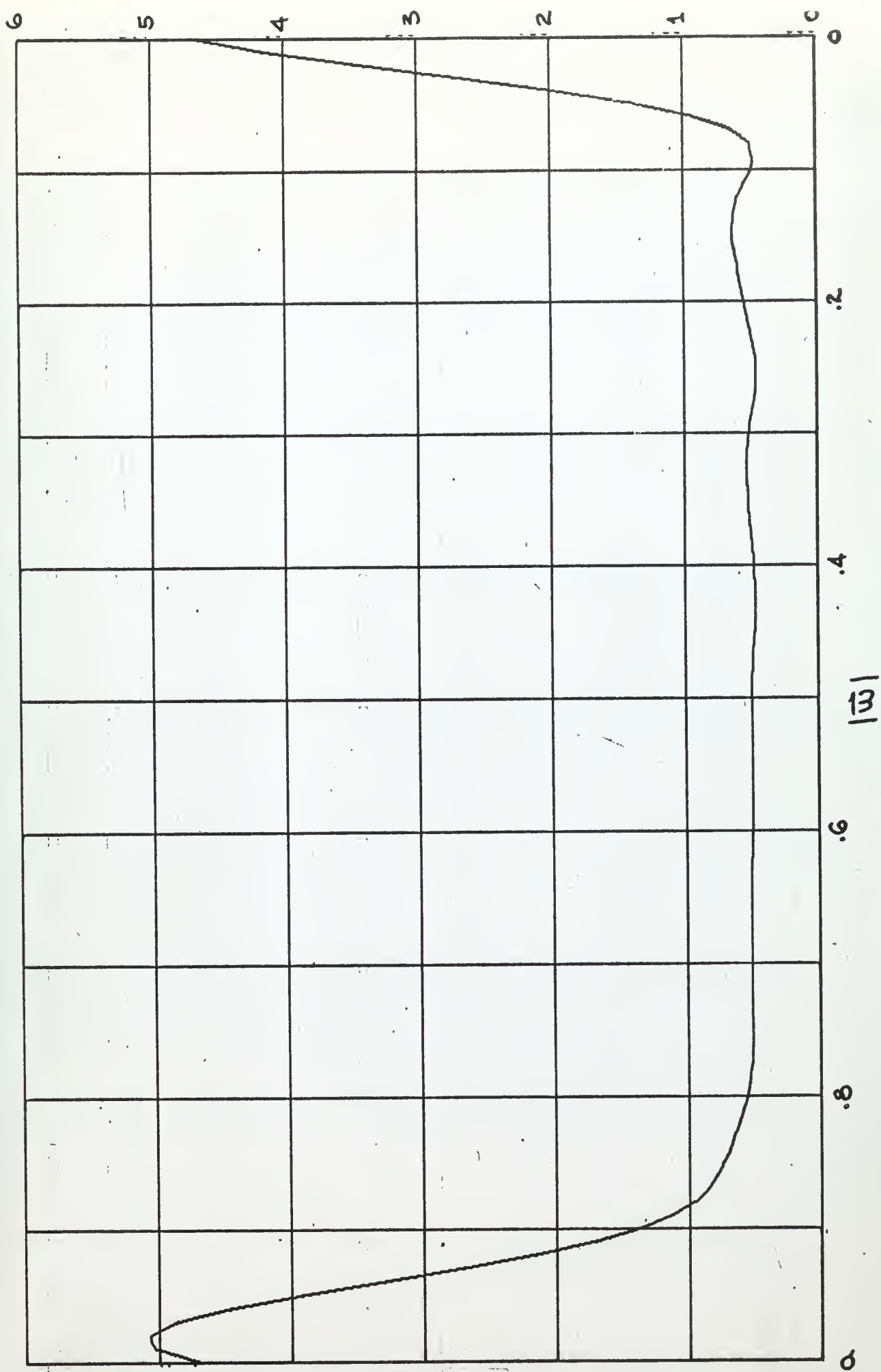


FIGURE 6. Patterson Function for specimen aged 1 day



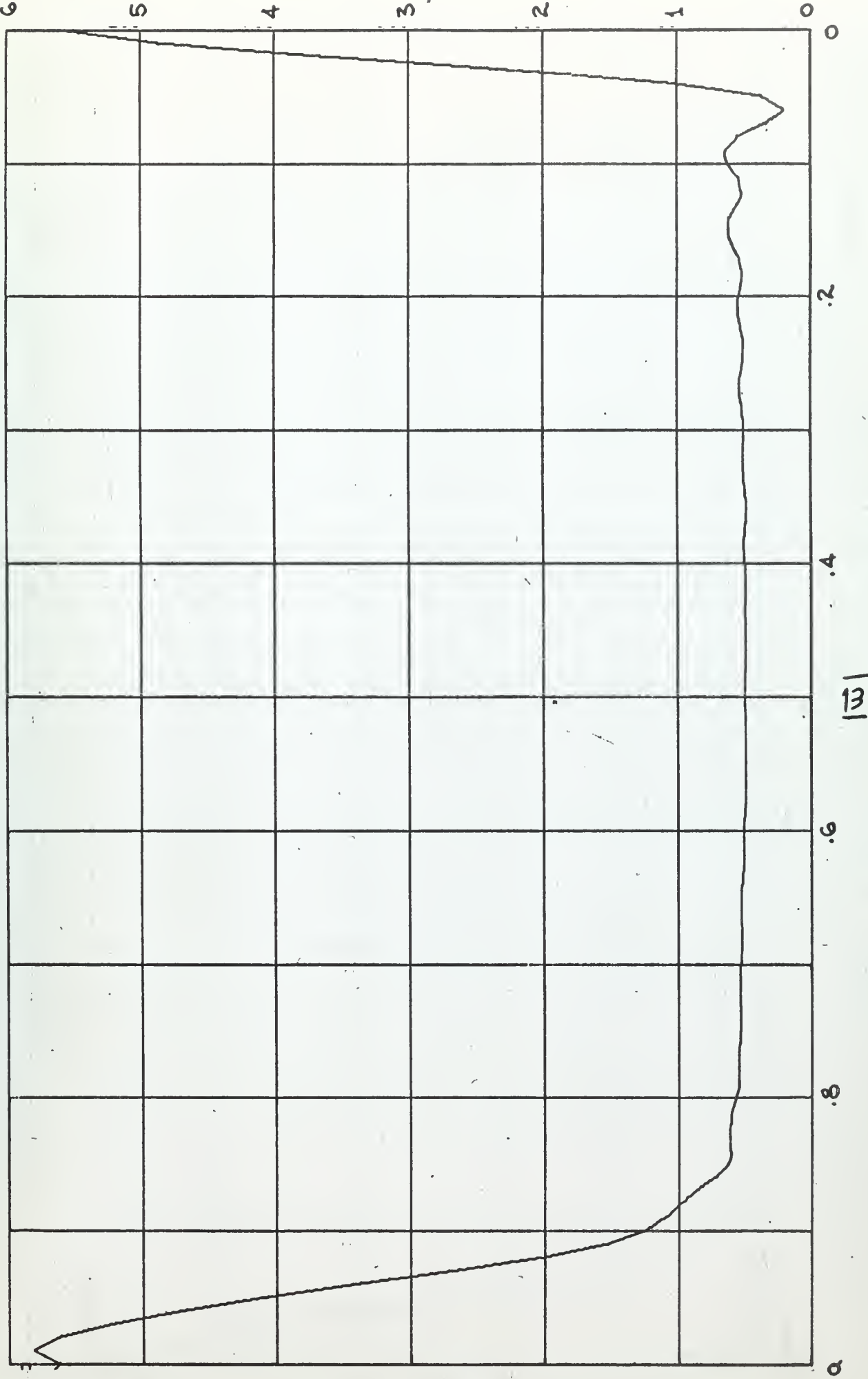


FIGURE 7. Patterson Function for specimen aged 2 days



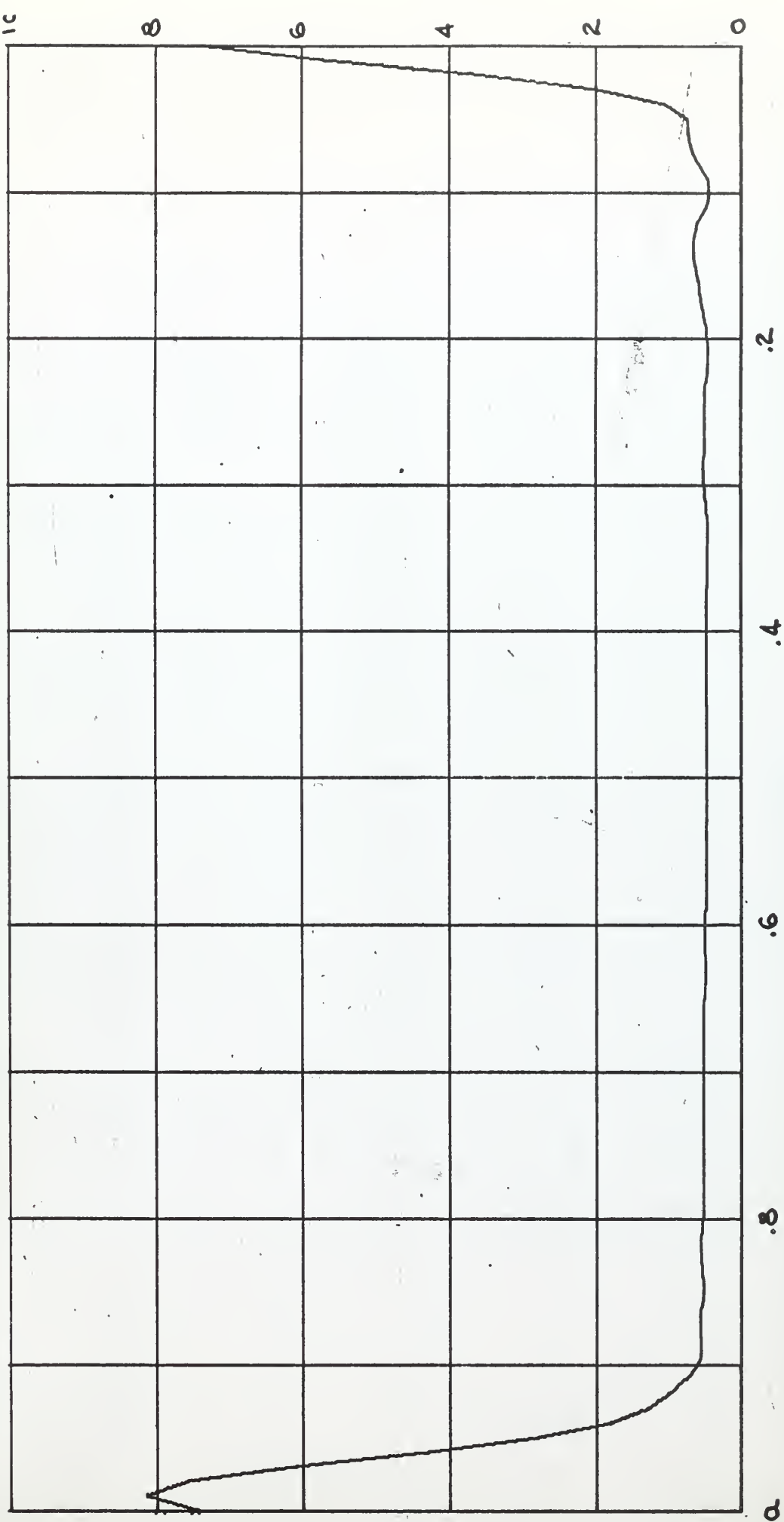
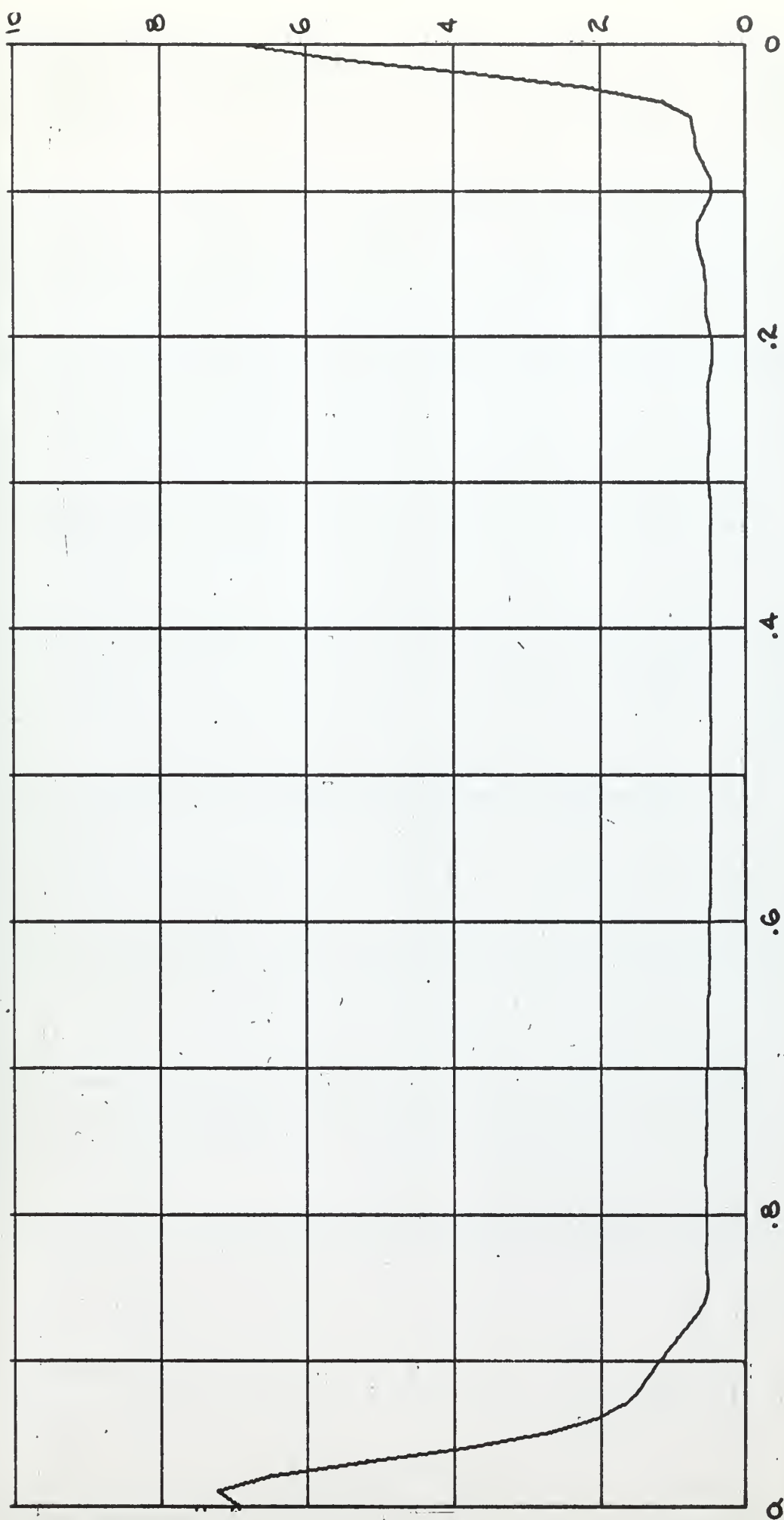


FIGURE 8. Patterson Function for specimen aged 5 days

13



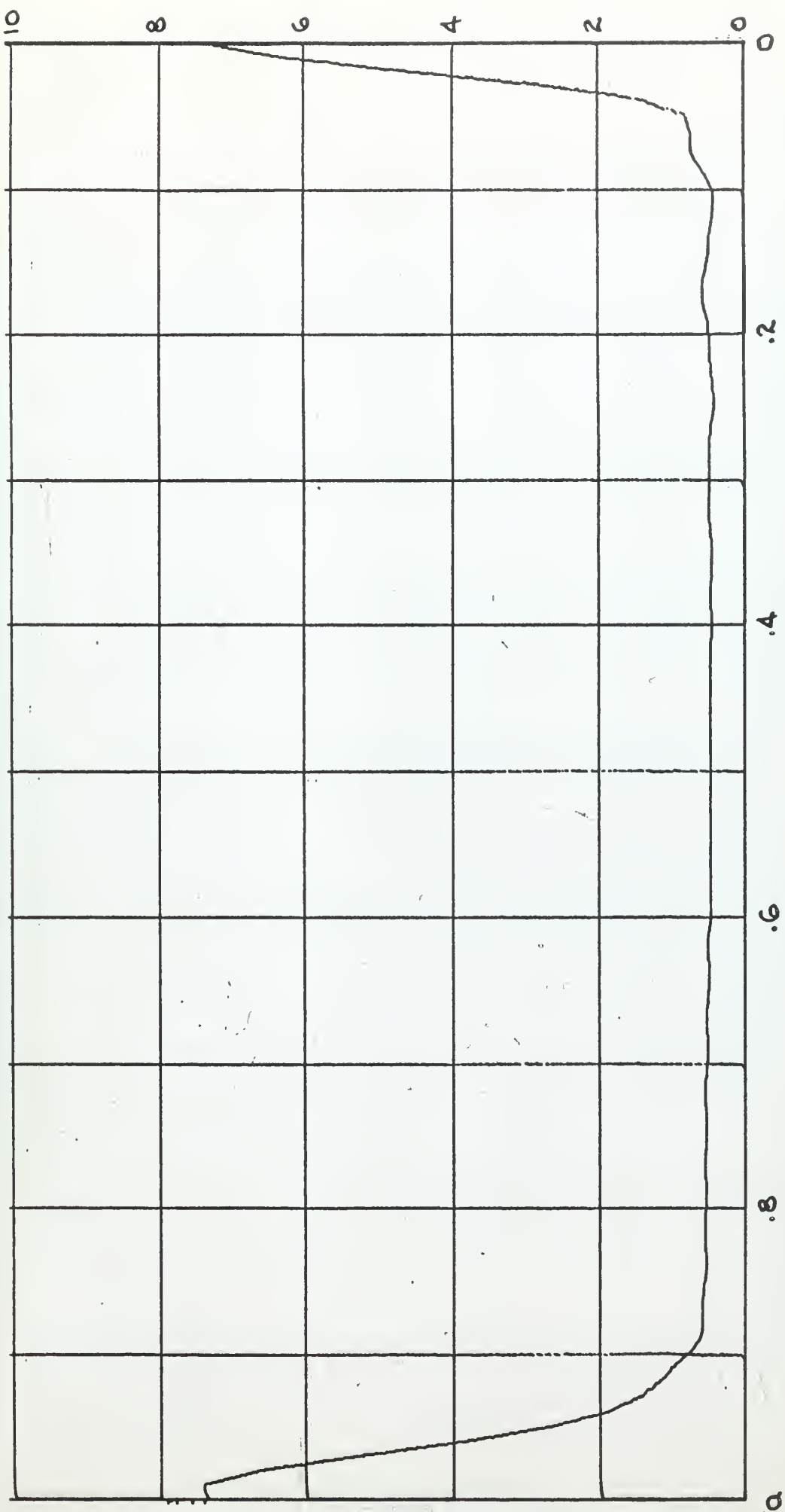


13

FIGURE 9. Patterson Function for specimen aged 9 days

1000

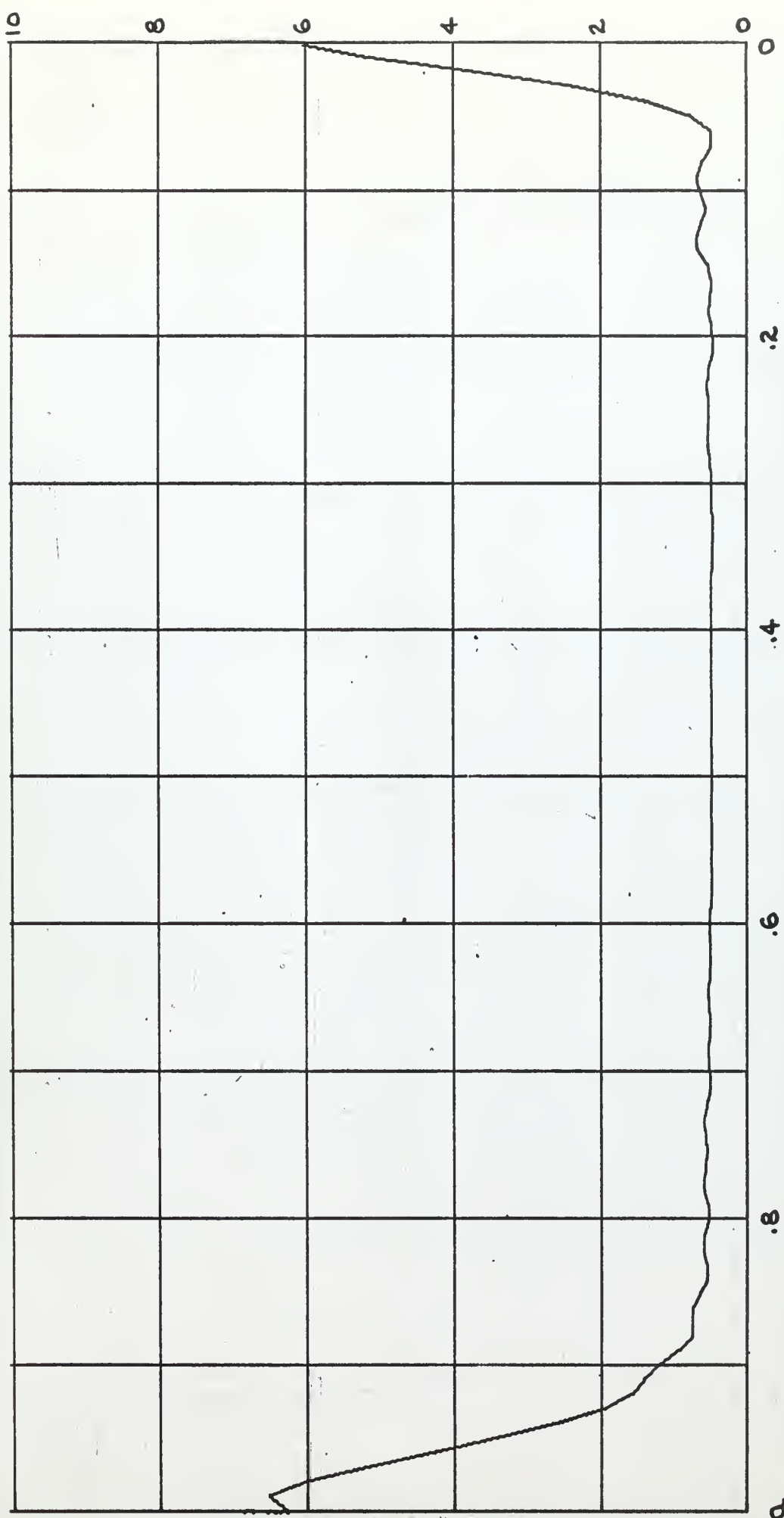




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FIGURE 10. Patterson Function for specimen aged 14 days

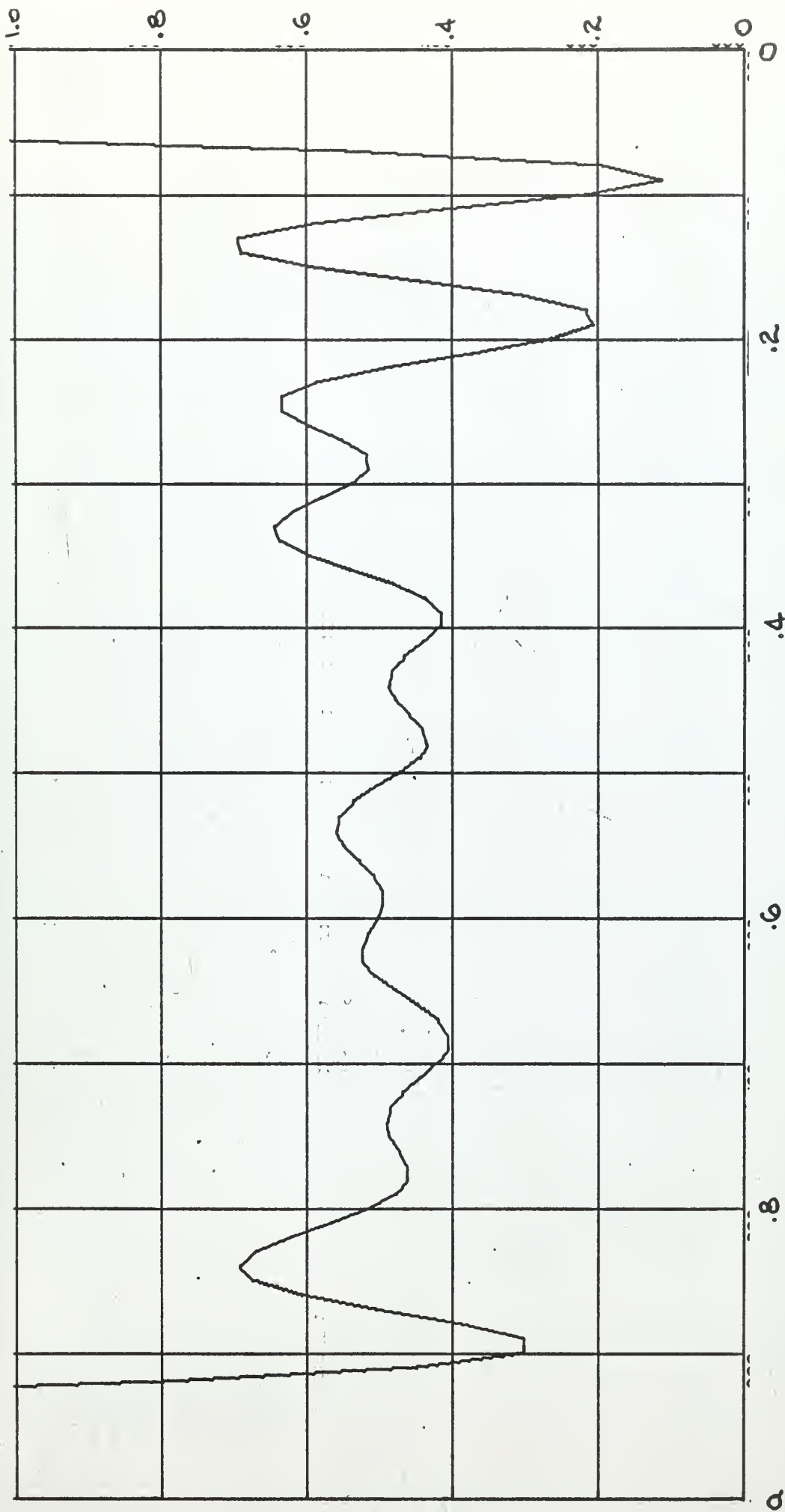




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FIGURE 11. Patterson Function for specimen aged 30 days





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FIGURE 12. Patterson Function, as quenched specimen

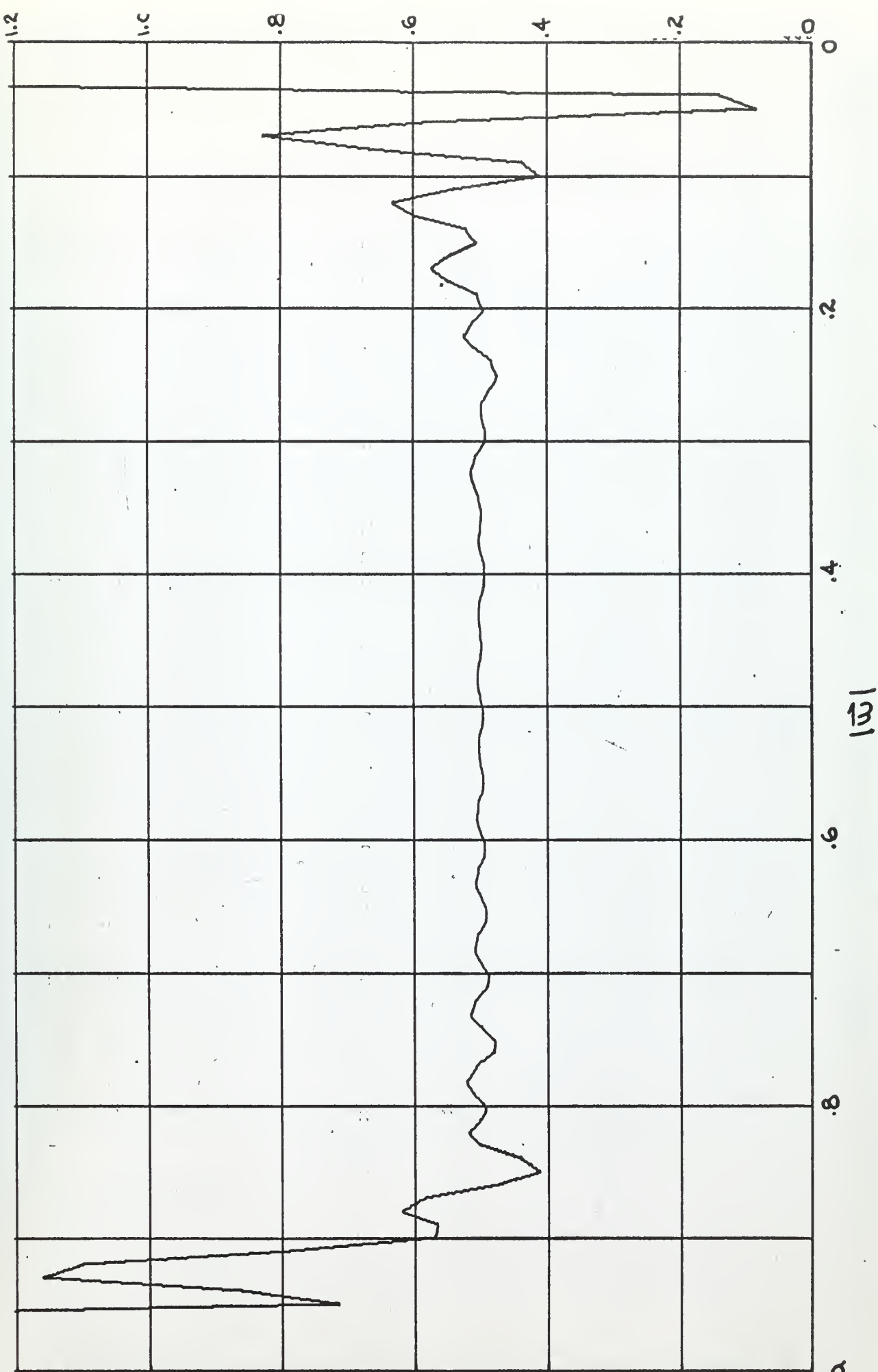


FIGURE 13. Patterson Function, aged 65 days at room temperature

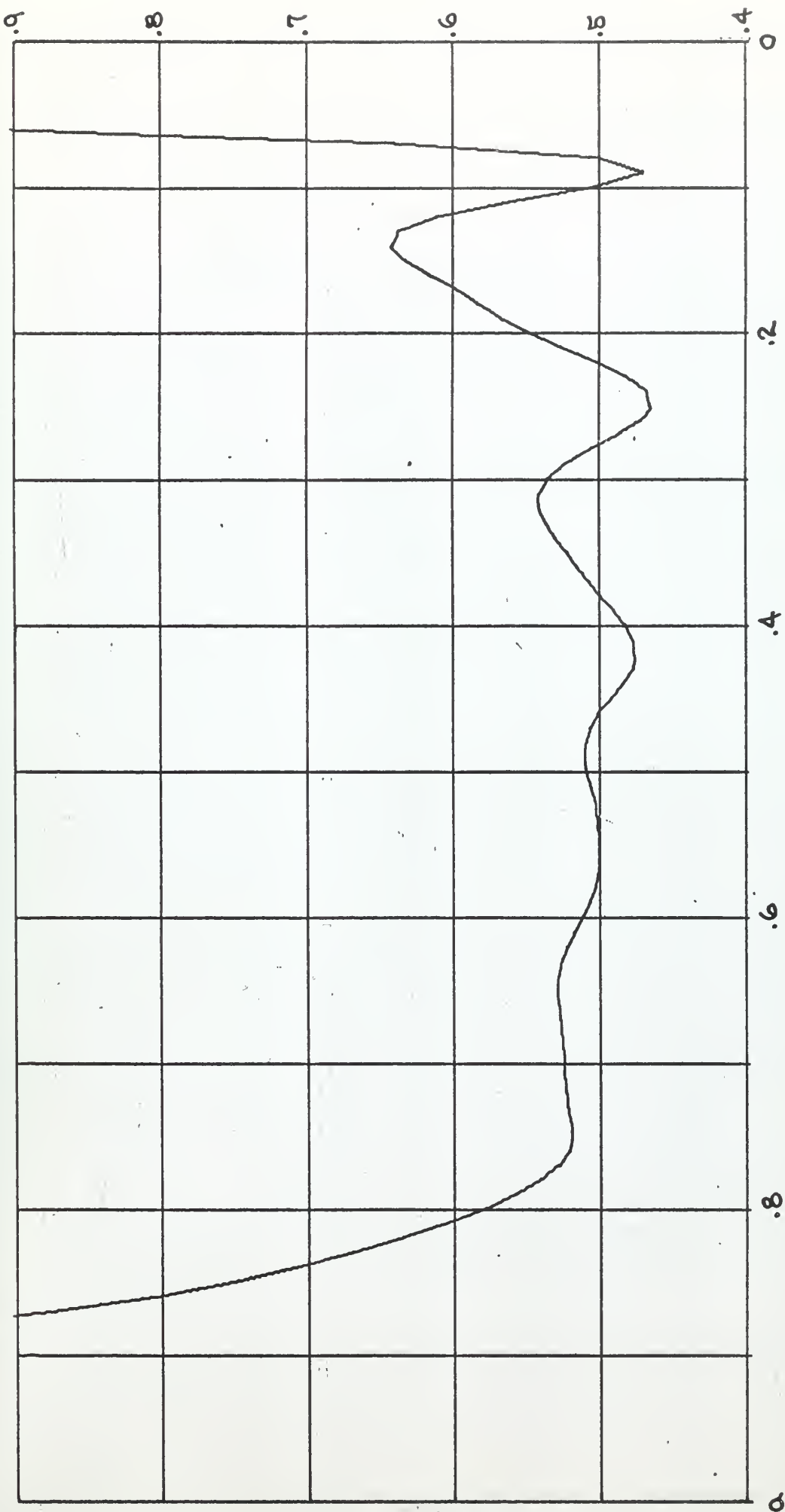


FIGURE 14. Patterson Function for specimen aged 1 day

131

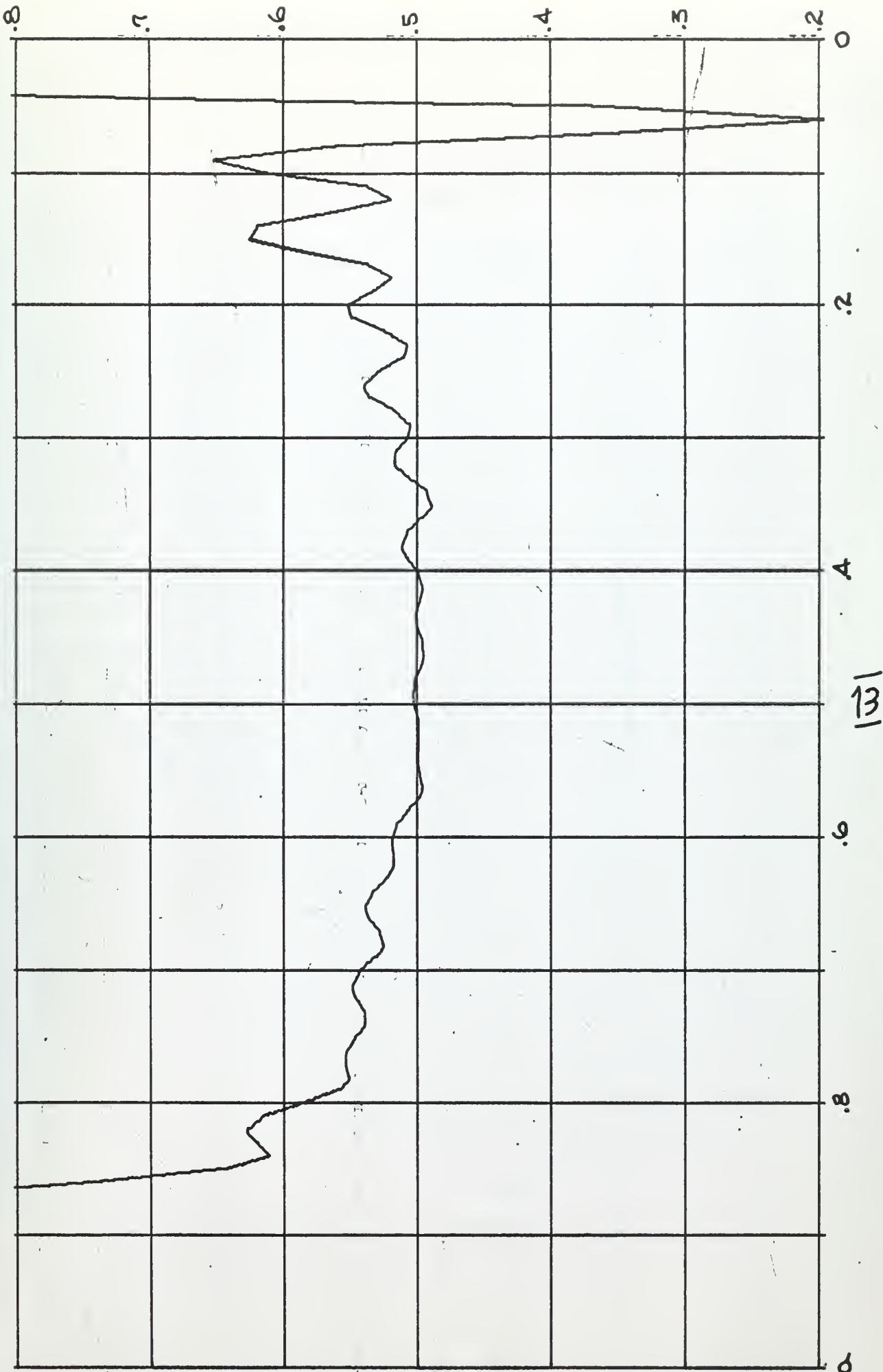


FIGURE 15. Patterson Function for specimen aged 2 days

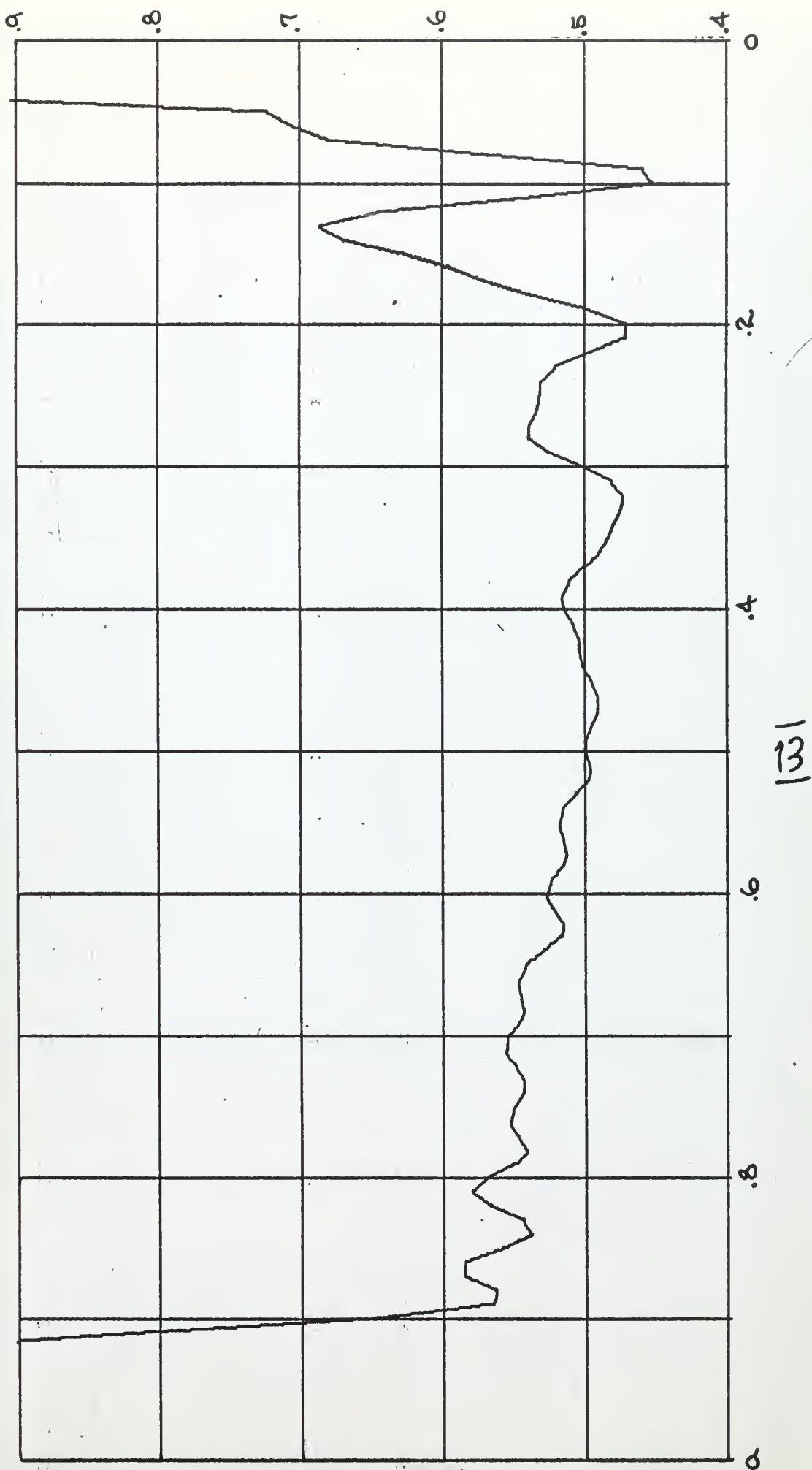


FIGURE 16. Patterson Function for specimen aged 5 days

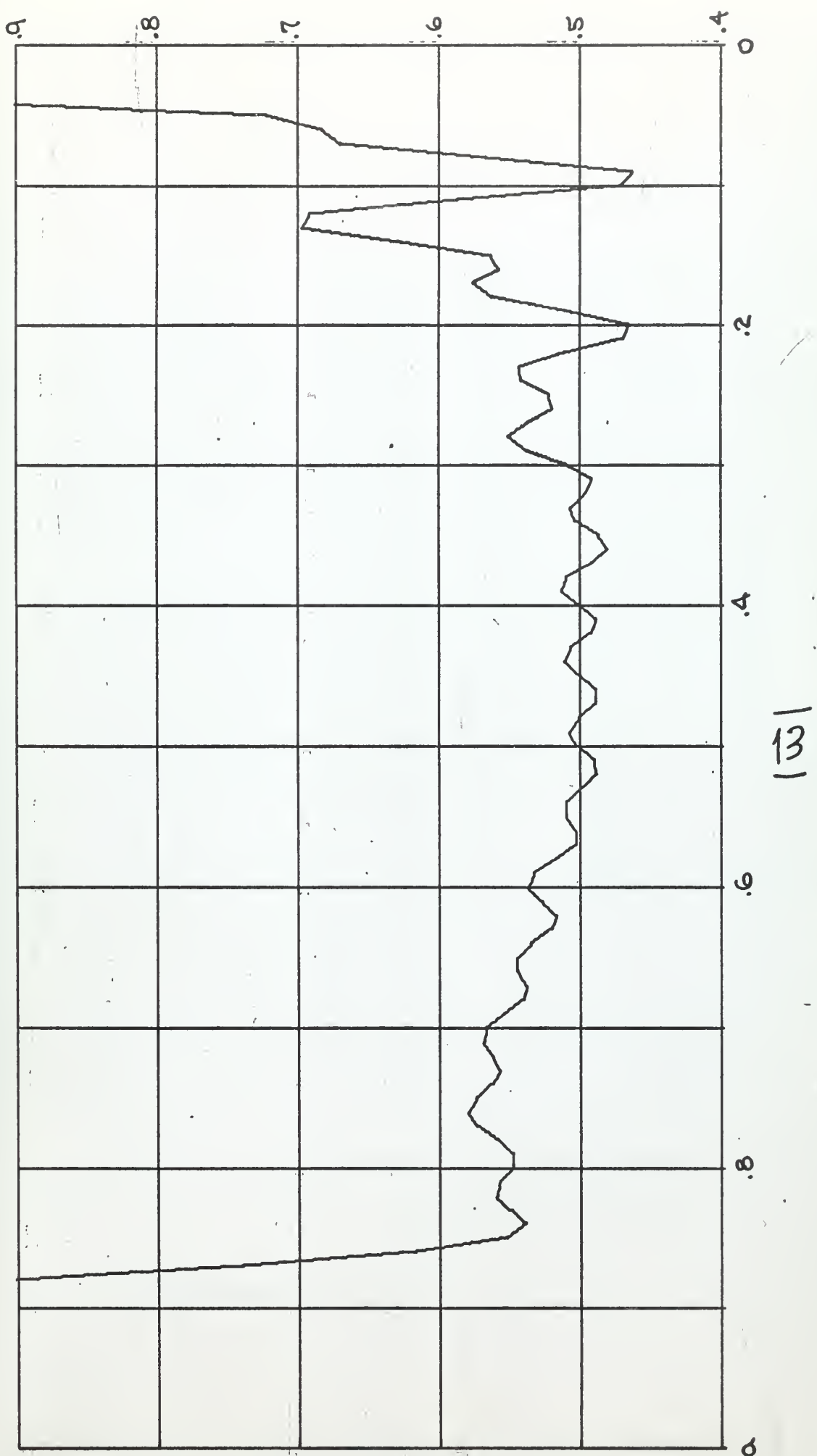


FIGURE 17. Patterson Function for specimen aged 9 days

131

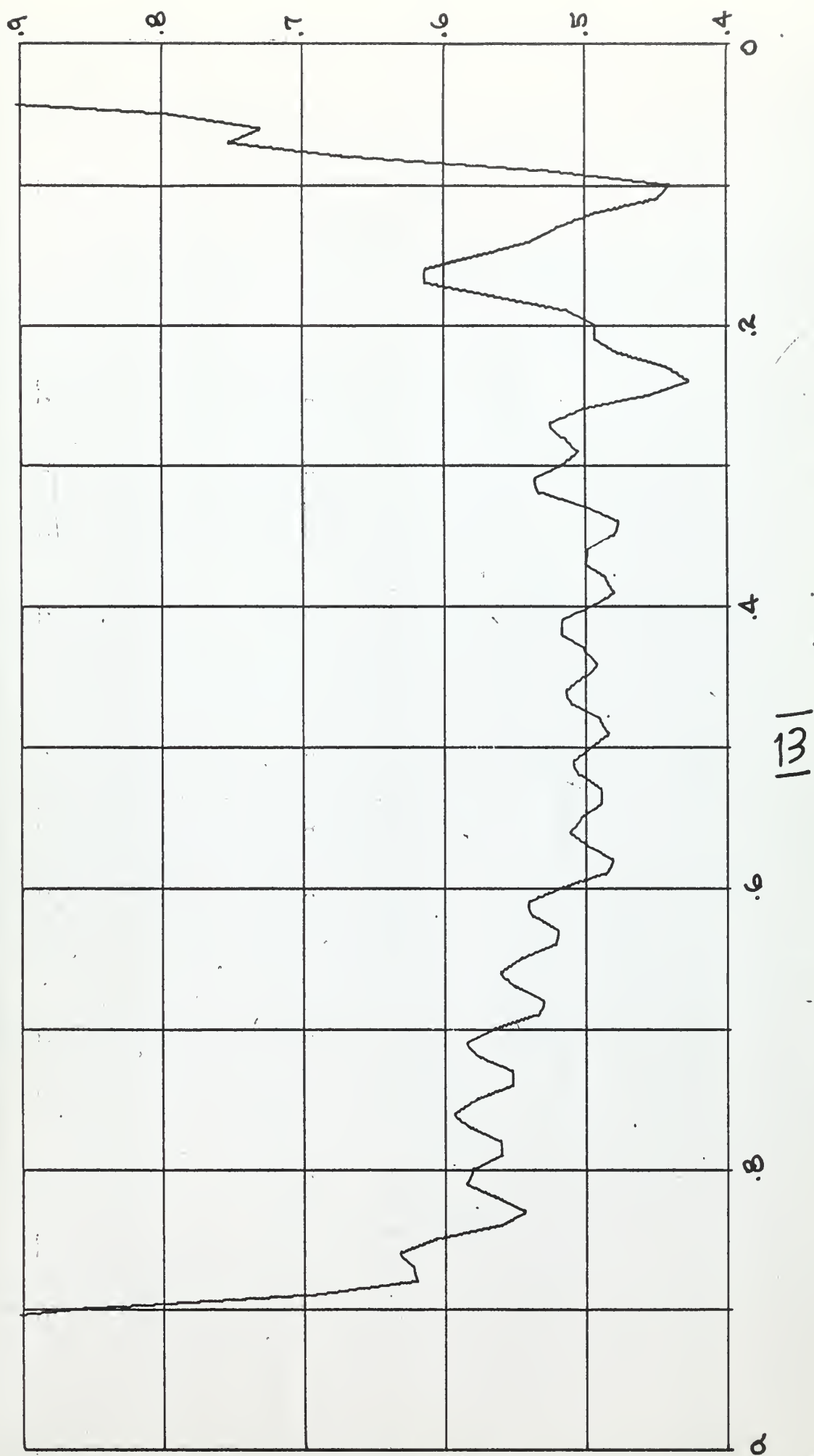


FIGURE 18. Patterson Function for specimen aged 14 days

131

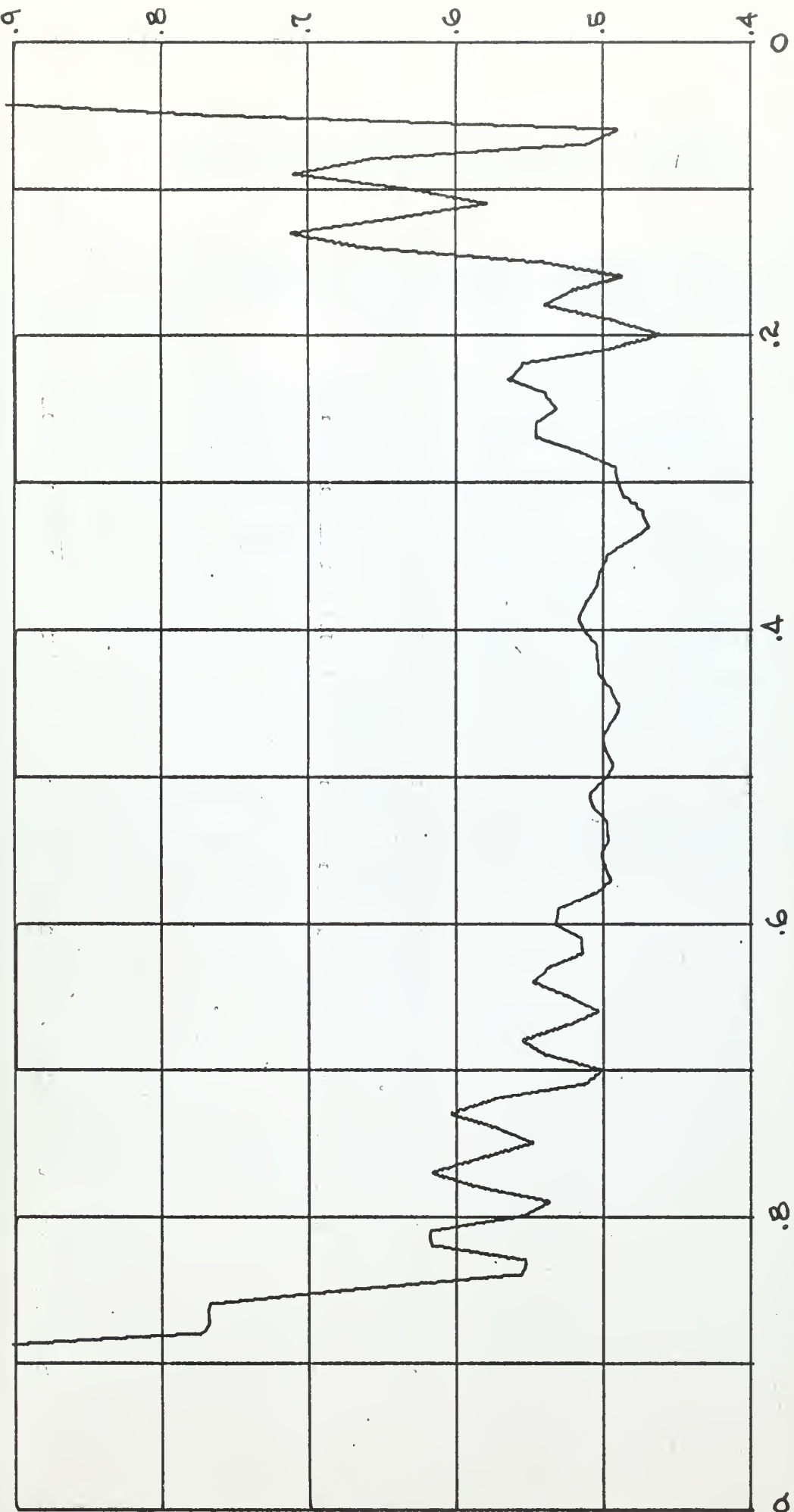


FIGURE 19. Patterson Function for specimen aged 30 days

APPENDIX II

FOURIER COEFFICIENTS FOR REFERENCE, BROADENED AND CORRECTED PROFILES

The column headings for the tabulated Fourier coefficients are as follows:

N, the harmonic number

ALPHA, coefficient of the real component

BETA, coefficient of the imaginary component

INTENSITY for each harmonic is computed by

$$I_N = \frac{L}{2} (A_N^2 + B_N^2)$$

where L is the number of equal intervals
between the data points used to describe
the curve.

The corrected coefficients are normalized. The arrow in the "corrected" column indicates the number of harmonics used in the synthesis of the Patterson function.

ALUMINUM - COPPER, AS QUENCHED, ALPHA(200)

REFERENCE				BROADENED				CORRECTED			
N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	BETA	INTENSITY
0	424.5239	0.000	*	377.9841	0.000	*	1.0000	0.000	36.50000		
1	-356.0011	-85.1635	*	-315.7390	-62.5321	*	.9868	-0.0388	35.59956		
2	218.7512	107.1233	*	191.0332	70.1629	*	.9334	-0.0968	32.14162		
3	-116.5124	-56.5779	*	-95.6457	-32.2461	*	.8682	-0.1108	27.96028		
4	179.5109	-18.0741	*	52.8696	-15.3019	*	.7568	-0.0441	20.97800		
5	-88.9668	64.5325	*	-44.2284	44.0159	*	.6300	-0.0987	14.84041		
6	110.3999	-67.9993	*	44.3316	-42.7636	*	.5212	-0.1140	10.39029		
7	-113.7543	44.1530	*	-36.9466	25.3555	*	.4015	-0.0945	6.20902		
8	95.7418	-16.9306	*	22.9504	-8.8440	*	.2789	-0.0544	2.94636		
9	-67.3357	1.5459	*	-9.1314	-17.2730	44.55541	.1522	-0.0064	.84657		
10	39.2998	0.324	*	7309	1.8143	139.64358	0.209	0.518	11405		
11	-20.4230	6.7041	*	1.8473	-1.2335	180.09652	0.118	0.311	.49167		
12	11.7353	-14.0901	*	-1.7849	-1.2316	171.64316	0.1279	-0.0357	.64391		
13	-9.3183	17.6994	*	.9584	-1.1693	83.43677	0.0832	-0.0170	.26305		
14	9.3500	-17.5258	*	-4.958	1.0462	48.92149	0.0654	0.0031	.15640		
15	-8.8448	14.7399	*	3329	-9042	33.88971	0.0619	0.117	.14467		
16	7.4495	-11.1888	55398	-2103	7612	22.76525	0.0627	0.0206	.15893		
17	-5.7849	8.1215	97263	6779	-5028	26.00083	0.0904	-0.0293	.32988		
18	4.0941	-5.4134	43104	-1.1662	1887	50.94018	0.1413	-0.1351	1.39486		
19	-2.4570	3.0678	86527	1.1371	1584	48.10659	0.1678	-0.2819	3.92807		
20	3876	-1.4035	77.38596	-7300	-6084	32.96068	0.3025	-0.6677	19.61029		
21	1.6177	1.0510	135.83905	2431	6384	17.03124	0.3211	0.2346	5.77260		
22	-2.5346	-1.7223	342.75231	267	-6374	5.50576	0.3722	0.1374	1.73958		
23	2.4615	2.0579	375.72000	-1904	0594	12.85055	0.1452	0.1485	1.57473		
24	-1.8775	-1.9165	262.72223	8686	2941	30.69483	0.3424	0.1736	5.37921		
25	1.0426	1.7232	148.06382	-6953	-1965	19.05519	0.2945	0.2750	5.92536		
26	0.369	-1.2941	61.17480	3999	-4556	13.41486	0.4050	0.3355	10.09633		
27	-1.0065	1.2893	40.02807	-4683	-1.3297	72.53882	0.8766	0.3319	83.43645		
28	1.0148	1.3059	99.83289	9769	-1.8255	156.46142	0.5718	-1.2845	72.15785		
29	-0.0289	-2.4648	221.77489	-1.2316	1.4163	128.57776	0.6387	-0.5687	26.69337		
30	-1.0579	2.4708	263.67316	9437	-5095	41.97995	0.3509	-0.2787	7.33037		

ALUMINUM - COPPER, AGED 65 DAYS, ROOM TEMP.

REFERENCE					BROADENED					CORRECTED				
N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	BETA	INTENSITY
0	212.2636	0000	*	320.0457	0000	*	1.0000	0000	72.50000	1.0000	0000	72.50000		
1	-202.8862	-23.7948	*	-303.2955	-23.0191	*	.9867	-.0405	70.70556	.9867	-.0405	70.70556		
2	-177.5764	-42.7913	*	-259.5999	-39.7807	*	.9502	-.0804	65.92799	.9502	-.0804	65.92799		
3	-143.4071	-53.2603	*	-203.7834	-46.9685	*	.8991	-.1167	59.59689	.8991	-.1167	59.59689		
4	-108.4696	-53.4296	*	-149.5422	-44.4720	*	.8436	-.1436	53.09314	.8436	-.1436	53.09314		
5	-78.8768	-43.9264	*	-104.2937	-33.8684	*	.7904	-.1554	47.04428	.7904	-.1554	47.04428		
6	-57.5536	-27.5293	*	-70.4234	-17.6193	*	.7395	-.1507	41.28969	.7395	-.1507	41.28969		
7	-44.8248	-8.2410	*	-48.1398	-7.7956	*	.6869	-.1381	35.58930	.6869	-.1381	35.58930		
8	-39.6414	-9.9494	*	-36.2017	-17.4563	*	.6387	-.1317	30.83802	.6387	-.1317	30.83802		
9	-40.3553	24.0817	*	-31.6977	-29.4080	*	.5968	-.1272	26.99830	.5968	-.1272	26.99830		
10	44.8642	-32.6689	*	30.9983	-35.5281	*	.5494	-.1252	23.01831	.5494	-.1252	23.01831		
11	-50.7073	-35.5883	*	-31.2676	-36.1215	*	.4962	-.1242	18.96633	.4962	-.1242	18.96633		
12	-55.5099	-33.6947	*	-30.9134	-32.3255	*	.4412	-.1184	15.13232	.4412	-.1184	15.13232		
13	-57.6571	-28.4092	*	-29.1141	-25.9102	*	.3876	-.1070	11.72503	.3876	-.1070	11.72503		
14	-56.6511	-21.3702	*	-25.5672	-18.8386	*	.3349	-.0942	8.77735	.3349	-.0942	8.77735		
15	-52.8971	14.1218	*	-20.6089	12.5489	*	.2804	-.0825	6.19405	.2804	-.0825	6.19405		
16	-47.1718	-7.8516	*	-15.0723	-7.5947	*	.2235	-.0696	3.97242	.2235	-.0696	3.97242		
17	-40.2287	3.2504	*	-9.8276	4.0385	*	.1663	-.0531	2.21016	.1663	-.0531	2.21016		
18	-32.7375	-3.5394	*	-5.4741	-1.8355	*	.1115	-.0353	.99164	.1115	-.0353	.99164		
19	-25.3779	-3.3958	*	-2.3135	.7364	*	.0601	-.0202	.29180	.0601	-.0202	.29180		
20	18.8201	-1.260	*	3742	-2071	*	.0132	-.0072	.01647	.0132	-.0072	.01647		
21	-13.5507	1.6542	*	.5647	.2242	*	.0286	-.0075	.06317	.0286	-.0075	.06317		
22	9.72239	-3.6652	10211	.8563	.6535	84.12274	.0658	.0198	.34266	.0658	.0198	.34266		
23	-7.19243	5.6586	108140	.8341	.9701	118.67171	.0910	.0179	.62329	.0910	.0179	.62329		
24	5.6763	-7.2762	174.31331	.7389	1.1731	139.34205	.0991	.0100	.71971	.0991	.0100	.71971		
25	-4.9044	8.3603	11.24466	.6966	-1.3618	169.61878	.1045	.0060	.79417	.1045	.0060	.79417		
26	4.3383	-8.9116	7317.45548	.7170	-1.5490	211.22686	.1126	.0052	.92056	.1126	.0052	.92056		
27	-4.6388	8.9936	7424.20080	.7541	-1.6601	241.02856	.1194	.0059	1.03534	.1194	.0059	1.03534		
28	4.6763	-8.6738	7039.96705	.7902	-1.6534	243.45932	.1232	.0060	1.10286	.1232	.0060	1.10286		
29	-4.5967	8.0321	16209.17603	.8365	-1.5186	217.92803	.1242	.0020	1.11929	.1242	.0020	1.11929		
30	4.3638	-7.1866	5124.97061	.8836	1.2113	162.98581	.1179	-.0100	1.01420	.1179	-.0100	1.01420		

ALUMINUM - COPPER, AGED 1 DAY, ALPHA(200)

REFERENCE					BROADENED					CORRECTED				
N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY		
0	272.9092	0.000	*	633.5042	0.000	*	1.0000	0.000	28.50000	0.000	0.000	28.50000		
1	-253.3929	-38.3807	*	-556.2850	5.4915	*	.9232	-1.492	24.92215	-1.492	-1.492	24.92215		
2	-204.1382	64.2012	*	400.4425	-0.0140	*	.7690	-2.419	18.52048	-2.419	-2.419	18.52048		
3	-145.9263	-69.5118	*	-252.6605	-2.2755	*	.6083	-2.889	12.92344	-2.889	-2.889	12.92344		
4	97.1253	54.0857	*	136.9401	-6.2747	*	.4518	-2.794	8.04240	-2.794	-2.794	8.04240		
5	-65.9009	-25.2199	*	-66.0147	18.1046	*	.3369	-2.473	4.97759	-2.473	-2.473	4.97759		
6	-52.0676	-6.1652	*	-28.6231	-26.5200	*	.2592	-1.887	2.92944	-1.887	-1.887	2.92944		
7	-51.8159	30.6997	*	-11.2459	-26.0159	*	.1641	-1.151	1.17143	-1.151	-1.151	1.17143		
8	-59.6443	-43.6824	*	5.5405	-20.3287	*	.0960	-0.765	.42962	-0.765	-0.765	.42962		
9	-68.9126	45.0810	*	-4.2348	-11.8307	*	.0524	-0.397	.12331	-0.397	-0.397	.12331		
10	73.9499	-37.8842	*	3.4670	-4.8932	*	.0276	-0.144	.02755	-0.144	-0.144	.02755		
11	-72.4441	26.3834	*	-1.7481	.7104	*	.0105	-0.004	.00317	-0.004	-0.004	.00317		
12	-65.3251	-14.7309	*	-5.5273	.1465	*	.0036	-0.002	.00037	-0.002	-0.002	.00037		
13	-54.2831	5.8030	*	2.0573	.0106	*	.0160	-0.018	.00740	-0.018	-0.018	.00740		
14	42.4343	-7.7761	*	-2.0831	.3735	*	.0012	-0.034	.01315	-0.034	-0.034	.01315		
15	-30.4131	-4.971	*	1.6064	-9.232	*	.0225	.0134	.01962	.0134	.0134	.01962		
16	-20.3702	-1.0859	*	-1.2755	1.3035	*	.0285	.0260	.04242	.0260	.0260	.04242		
17	-13.2810	4.2160	*	-1.2681	-1.3018	*	.0469	.0181	.07204	.0181	.0181	.07204		
18	9.0062	-7.5043	*	-7.8808	1.0862	*	.0243	-0.161	.02419	-0.161	-0.161	.02419		
19	-6.8247	9.9695	*	.5258	1.2750	*	.0269	-0.412	.06893	-0.412	-0.412	.06893		
20	6.0248	-11.2912	*	-4.8227	-2.2009	*	.0577	-0.452	.16395	-0.452	-0.452	.16395		
21	-5.9605	11.5713	*	.4903	2.3768	*	.0625	-0.504	.18386	-0.504	-0.504	.18386		
22	-5.0063	-10.9942	*	-6.1005	-2.2178	*	.0569	-0.550	.22128	-0.550	-0.550	.22128		
23	-5.7784	9.7902	*	1.0703	2.0642	*	.0467	-0.747	.32517	-0.747	-0.747	.32517		
24	-5.2708	-8.3076	*	-1.7418	-1.7080	*	.0223	-1.045	.59368	-1.045	-1.045	.59368		
25	4.6351	6.7283	*	1.8352	1.3217	*	.0036	-1.175	.39936	-1.175	-1.175	.39936		
26	-3.9443	-5.5973	*	-1.5581	-5.650	*	.0274	-1.006	.30936	-1.006	-1.006	.30936		
27	-3.2275	4.4295	*	-1.0780	-5.379	*	.0841	-0.436	.25558	-0.436	-0.436	.25558		
28	-2.5407	-3.3352	*	-4.140	1.6264	*	.1587	-0.674	.84746	-0.674	-0.674	.84746		
29	-1.8742	2.3417	*	-4.140	-1.6264	*	.1452	-1.524	.65598	-1.524	-1.524	.65598		
30	1.1128	-1.4940	*	1.0780	.5379	*	.0492	-2.742	2.21209	-2.742	-2.742	2.21209		

ALUMINUM - COPPER, AGED 2 DAYS, (200)

REFERENCE				BROADENED				CORRECTED				
N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY
0	212.2636	0000	*	344.4746	0000	*	1.0000	0000	*	1.0000	0000	*
1	-202.8862	-23.7948	*	-310.9229	19.4131	*	.9247	-.1674	*	.9247	-.1674	*
2	177.5764	-42.7913	*	-245.0116	-24.3435	*	.7843	-.2735	*	.7843	-.2735	*
3	-143.4071	-53.2603	*	-180.8538	22.5434	*	.6513	-.3387	*	.6513	-.3387	*
4	108.4696	53.4296	*	-121.3857	-17.0968	*	.5164	-.3515	*	.5164	-.3515	*
5	-78.8768	-43.9264	*	-74.5381	12.1202	*	.4042	-.3198	*	.4042	-.3198	*
6	57.5536	27.5293	*	41.5659	-11.1965	*	.3155	-.2708	*	.3155	-.2708	*
7	-44.8248	-8.2410	*	-20.6456	11.7631	*	.2458	-.2069	*	.2458	-.2069	*
8	39.6414	-9.9494	*	10.0908	-12.3421	*	.1929	-.1434	*	.1929	-.1434	*
9	-40.3539	24.0817	*	-6.1504	11.7078	*	.1479	-.0905	*	.1479	-.0905	*
10	44.8642	-32.6689	*	6.0773	-9.7776	*	.1185	-.0480	*	.1185	-.0480	*
11	-50.7073	35.5883	*	-6.7113	6.4467	*	.0915	-.0141	*	.0915	-.0141	*
12	55.5099	-33.6947	*	6.8822	-2.6636	*	.0689	-.0123	*	.0689	-.0123	*
13	-57.6571	28.4092	*	-6.4844	2.8414	*	.0522	.0347	*	.0522	.0347	*
14	56.6511	-21.3702	*	5.3601	2.9456	*	.0405	.0473	*	.0405	.0473	*
15	-52.8971	14.1218	*	-3.6652	-3.2905	*	.0303	.0464	*	.0303	.0464	*
16	47.1718	-7.8516	*	1.9539	2.8048	*	.0189	.0398	*	.0189	.0398	*
17	-40.2287	3.2504	*	-1.5354	-1.3138	*	.0065	.0207	*	.0065	.0207	*
18	32.7375	-5.3394	*	-1.1272	.0798	*	.0024	.0015	*	.0024	.0015	*
19	-25.3779	-21.3702	*	.3888	.6638	*	.0097	-.0160	*	.0097	-.0160	*
20	18.8201	-1.260	*	-6704	-1.1941	*	.0217	-.0392	*	.0217	-.0392	*
21	-13.5507	1.6542	*	.8325	.9234	*	.0322	-.0459	*	.0322	-.0459	*
22	9.7234	-3.6652	*	-1.0393	-2.046	*	.0534	-.0331	*	.0534	-.0331	*
23	-9.1924	6.6566	*	.9628	.4159	*	.0682	-.0182	*	.0682	-.0182	*
24	5.6763	-7.2762	*	-9739	.4753	*	.0650	-.0318	*	.0650	-.0318	*
25	-4.9044	8.3603	*	1.0220	.1024	*	.0273	-.0593	*	.0273	-.0593	*
26	4.6383	-8.9116	*	-.9250	-.7133	*	.0126	-.0705	*	.0126	-.0705	*
27	-4.6388	8.9936	*	8047	1.3969	*	.0531	-.0825	*	.0531	-.0825	*
28	4.6765	-8.6738	*	-7443	-2.1382	*	.0956	-.1044	*	.0956	-.1044	*
29	-4.5967	8.0321	*	.5055	2.0800	*	.1035	-.0980	*	.1035	-.0980	*
30	4.3638	-7.1866	*	-.0843	-1.8956	*	.1155	-.0774	*	.1155	-.0774	*

REFERENCE

BROADENED

CORRECTED

N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY
0	212.2636	0.000	*	380.2606	0.000	*	1.0000	0.000	36.50000
1	-202.8862	-2.7948	*	-347.5288	-6.4187	*	.9452	-.0932	32.92859
2	177.5764	22.7913	*	-286.1070	21.0600	*	.8651	-.1423	28.05436
3	-143.4071	-53.2603	*	-223.4243	-22.7071	*	.7931	-.2062	24.51022
4	108.4696	53.4296	*	161.4440	18.0164	*	.7054	-.2547	20.52775
5	-78.8768	-43.9264	*	-108.8494	-9.4644	*	.6164	-.2763	16.65670
6	57.5536	27.5293	*	68.0840	3.0401	*	.5259	-.2810	12.97811
7	-44.8248	-9.2410	*	-40.0333	14.8376	*	.4494	-.2674	9.98049
8	39.6414	8.9494	*	21.6672	22.4212	*	.3616	-.2250	6.61911
9	-40.3539	24.0817	*	-11.4631	-26.3574	*	.2774	-.2250	4.25453
10	44.7073	-32.6889	*	6.8892	-27.4251	*	.2168	-.1834	2.94250
11	-50.7039	35.6883	*	-5.4458	25.5109	*	.1721	-.1600	2.01622
12	55.5099	-35.6947	*	5.4410	-25.8855	*	.1376	-.1366	1.37174
13	-57.6571	28.4092	*	-5.8108	17.0901	*	.1109	-.1108	.89698
14	56.6511	-21.3702	*	5.7843	-12.0156	*	.0890	-.0848	.55169
15	-52.8971	14.1218	*	-4.9626	7.7403	*	.0692	-.0632	.32076
16	47.1718	-17.516	*	3.7744	-4.5245	*	.0487	-.0454	.16195
17	-40.2287	3.2504	*	-2.1525	2.1434	*	.0321	-.0272	.06443
18	32.3779	-3.3394	*	.8356	-7.7900	*	.0145	-.0132	.01403
19	-25.3779	3.3958	*	.0431	-.0156	*	-.0009	-.0004	.00004
20	18.8201	-1.260	*	-2.092	2.880	*	-.0063	-.0085	.00407
21	-13.5507	1.6522	*	-.4350	-1.3287	*	.0008	-.0056	.00115
22	9.7234	-3.6552	*	-.9178	3.1311	*	.0235	-.0053	.02023
23	-7.1923	5.6586	*	1.1286	-.0807	*	.0489	-.0283	.11672
24	5.6763	-7.2762	*	-.1917	7.0909	*	.0381	-.0568	.17098
25	-4.9044	8.3603	*	-1.1946	-.3028	*	.0198	-.0682	.18385
26	4.6383	-8.9116	*	.9716	12.500	*	.0188	-.0511	.10813
27	-4.6388	8.9367	*	-.4013	-.0093	*	.0097	-.0199	.01790
28	4.6763	-8.6738	*	-.0620	-.0031	*	-.0015	-.0032	.00045
29	-4.5967	8.0321	*	.1917	-.0672	*	-.0093	-.0080	.00548
30	4.3638	-7.1866	*	-.3360	7.1291	*	-.0188	-.0147	.02080

ALUMINUM - COPPER, AGED 9 DAYS (200)

REFERENCE

BROADENED

CORRECTED

N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY
0	212.2636	0000	*	424.2419	0000	*	1.0000	0000	36.50000
1	-202.8862	-23.7948	*	-382.4330	3.9066	*	.9292	-.1186	32.02837
2	-177.5764	-42.7913	*	-305.1963	6.5432	*	.8169	-.1784	25.52057
3	-143.4071	-53.2603	*	-230.9527	-10.3074	*	.7198	-.2314	20.86745
4	-108.4696	-53.4296	*	-158.5492	-10.0812	*	.6070	-.2525	15.77388
5	-78.8768	-43.9264	*	-100.6373	-6.9083	*	.5059	-.2379	11.40673
6	-57.5536	-27.5293	*	61.0015	-2.2606	*	.4307	-.2083	8.35374
7	-44.8248	-8.2410	*	-37.1149	8.6211	*	.3836	-.1668	6.38650
8	-39.6414	-9.9494	*	-23.6549	-17.0099	*	.3316	-.1315	4.64345
9	-40.3539	24.0817	*	-16.8061	-22.4535	*	.2762	-.1136	3.25463
10	44.8642	-32.6689	*	13.2627	-24.6871	*	.2277	-.1095	2.32982
11	-50.7073	-35.5883	*	-11.1317	-23.2172	*	.1813	-.1018	1.57842
12	55.5099	-33.6947	*	9.7005	-19.5388	*	.1420	-.0899	1.03117
13	-57.6571	-28.4092	*	-8.3101	14.6153	*	.1083	-.0735	.62515
14	56.6511	-21.3702	*	7.0705	-9.5066	*	.0824	-.0529	.34986
15	-52.8971	14.1218	*	-5.9427	5.5071	*	.0655	-.0346	.20010
16	-47.1718	-7.8516	*	4.8500	-2.4835	*	.0543	-.0173	.11863
17	-40.2287	3.5504	*	-3.5517	.6164	*	.0445	-.0041	.07289
18	-32.7375	-3.5394	*	1.8694	.1824	*	.0285	.0033	.03007
19	-25.3779	-.3958	*	-2.066	-.6544	*	.0043	.0128	.00668
20	18.8201	-1.260	*	-1.1289	.3098	*	.0301	.0080	.03535
21	-13.5507	1.6542	*	1.5730	-.2392	*	.0583	.0017	.12412
22	9.72339	-3.6652	10211	-1.4903	.4465	*	.0747	-.0052	.20480
23	-7.19243	5.6586	6071.88140	1.5197	-.5672	*	.0845	-.0270	.28708
24	5.6763	-7.2762	6174.31331	-1.0860	.7890	*	.0699	-.0201	.19334
25	-4.9044	8.3603	6811.24466	1.1753	-.9592	*	.0734	.0273	.22383
26	4.6383	-8.9116	7317.45548	-1.2288	.8935	*	.0677	-.0337	.20899
27	-4.6388	8.9936	7424.20080	.9639	-.8302	*	.0583	-.0235	.14440
28	4.6763	-8.6738	7039.56705	-.5550	1.0841	*	.0618	.0013	.13958
29	-4.5967	8.0321	6209.17603	.0194	-1.2544	*	.0594	.0328	.16791
30	4.3638	-7.1866	5124.97061	.5901	1.2906	*	.0474	.0699	.26030

ALUMINUM - COPPER, AGED 13.8 DAYS, (200)

REFERENCE

BROADENED

CORRECTED

N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY
0	212.2636	0.000	*	316.6900	0.000	*	1.0000	0.000	72.50000
1	-202.8862	-23.7948	*	-289.9945	-2.1803	*	.8459	-.1037	65.61270
2	177.5764	42.7913	*	236.1304	17.1583	*	.8571	-.1418	54.41758
3	-143.4071	-53.2603	*	-180.9840	-24.6191	*	.7809	-.1750	46.43077
4	108.4696	53.4296	*	126.7580	20.7475	*	.6811	-.2073	36.75314
5	-78.8768	-43.9264	*	-82.4277	-13.7706	*	.5844	-.2084	27.90655
6	57.5536	27.5293	*	50.9876	4.0988	*	.5018	-.1923	20.93739
7	-44.8248	-27.2410	*	-29.7785	5.1430	*	.4170	-.1536	14.31913
8	39.6414	-9.9494	*	17.6923	-12.6012	*	.3317	-.1298	9.19938
9	-40.3539	24.0817	*	-11.7662	-17.1354	*	.2694	-.1239	6.37232
10	44.8642	-32.6689	*	10.2284	-18.1034	*	.2286	-.1040	4.57193
11	-50.7073	35.5883	*	-10.1302	16.6098	*	.1929	-.0841	3.21228
12	55.5099	-33.6947	*	9.8996	-13.0331	*	.1572	-.0620	2.06902
13	-57.6571	28.4092	*	-9.1858	9.1886	*	.1283	-.0436	1.33308
14	56.6511	-21.3702	*	7.3433	-5.6544	4227.42863	.0981	-.0299	.76312
15	-52.8971	14.1218	*	-5.2110	2.7422	513.91808	.0703	-.0160	.37676
16	47.1718	-7.8516	*	3.0788	-9.445	751.88555	.0447	-.0060	.14771
17	-40.2287	3.2504	*	-1.5577	-.0543	176.12715	.0257	.0030	.04857
18	32.7375	-3.5394	*	7.154	2.912	43.25245	.0145	.0062	.01813
19	-25.3779	-.3958	*	-2.030	-.5355	23.77860	.0056	.0141	.01658
20	18.8201	-.1260	*	.0521	7.075	36.48248	.0017	.0252	.04627
21	-13.5507	1.6542	*	.3099	-.6330	36.01388	.0189	.0290	.08682
22	9.7239	-3.6652	7829.10211	-.6355	4.786	45.88133	.0492	.0144	.19087
23	-7.1924	5.6586	6071.88140	-.8858	-.0818	57.36910	.0547	-.0354	.30773
24	5.6763	-7.2762	6174.31331	-1.0173	-.1442	76.53635	.0372	-.0647	.40374
25	-4.9044	8.3603	6811.24466	.8638	3.999	65.68729	-.0064	-.0655	.31411
26	4.6383	-8.9116	7317.45548	-.8275	-.6145	77.02411	.0109	-.0679	.34284
27	-4.6388	-8.9936	7424.20080	-.6962	5.986	61.12136	.0141	-.0592	.26814
28	4.6763	-8.6738	7039.96705	-.6213	-.5556	50.36376	.0132	-.0551	.26301
29	-4.5967	8.0321	6209.17603	.6748	2.239	36.64692	-.0102	-.0505	.19223
30	4.3638	-7.1866	5124.97061	-.6244	.1813	30.64891	-.0382	-.0350	.19478

ALUMINUM - COPPER, AGED 30 DAYS, (200)

REFERENCE

BROADENED

CCORRECTED

N	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY	ALPHA	BETA	INTENSITY
0	212.2636	.0000	*	365.4429	.0000	*	1.0000	.0000	36.50000
1	-202.8862	-23.7948	*	-334.1492	7.6581	*	.9309	-.1309	32.25673
2	177.5764	42.7913	*	263.6370	-1.5024	*	.8051	-.1589	25.10105
3	-143.4071	-53.2603	*	-194.6360	-2.2587	*	.6882	-.2466	19.50726
4	108.4696	53.4296	*	132.4841	2.6762	*	.5703	-.2668	14.47089
5	-78.8768	-43.9264	*	-83.0131	-6.498	*	.4636	-.2534	10.18717
6	57.5536	27.5293	*	47.6853	-5.0882	*	.3676	-.2266	6.80784
7	-44.8248	-8.2410	*	-27.0247	10.3078	*	.3116	-.1854	4.85273
8	39.6414	-9.9494	*	16.1152	-14.4511	*	.2692	-.1419	3.37958
9	-40.3539	24.0817	*	-10.1834	15.8331	*	.2061	-.1024	1.933357
10	44.8642	-32.6689	*	8.2661	-14.8716	*	.1598	-.0741	1.13247
11	-50.7073	35.5883	*	-7.6337	12.2128	*	.1230	-.0520	.65123
12	55.5099	-33.6947	*	7.0437	-8.9504	*	.0944	-.0354	.37068
13	-57.6571	38.4092	*	-5.8643	5.7135	*	.0696	-.0226	.19550
14	56.6511	-21.3702	*	4.7586	-2.7059	*	.0513	-.0081	.09849
15	-52.8971	14.1218	*	-3.3629	1.1023	*	.0371	-.0021	.05034
16	47.1718	-17.8516	*	1.8809	-1.1629	*	.0226	-.0018	.01878
17	-40.2287	3.2504	*	-1.9626	.3392	*	.0133	.0059	.00770
18	32.7375	-3.5394	*	.3708	.4919	*	.0064	.0087	.00426
19	-25.3779	-3.3958	*	-2.565	-1.1933	*	.0059	.0043	.00193
20	18.8201	-1.1260	*	.2569	-1.1092	*	.0079	-.0033	.00265
21	-13.5507	1.6542	*	-4.875	.2319	*	.0215	-.0072	.01884
22	9.7239	-3.6652	10211	.4960	.4876	10.63646	.0352	-.0156	.05398
23	-7.1924	5.6586	88140	-0.743	.3955	17.65696	.0192	-.0168	.02376
24	5.6763	-7.2762	74.31331	-6.681	-1.1278	16.88960	-.0193	-.0377	.06547
25	-4.9044	8.3603	6811.24466	1.3470	-1.1620	67.18876	-.0487	-.0640	.23608
26	4.6388	-8.9116	731.45548	-1.2787	.710	80.87907	-.0477	-.0705	.26453
27	-4.6388	8.9367	424.20080	1.2383	.0625	56.10834	-.0291	.0641	.18087
28	4.6763	-8.6738	7039.56705	-6.6038	.4874	21.97840	-.0083	-.0445	.07472
29	-4.5967	8.0321	6209.17603	-0.728	.9586	33.73078	.0539	-.0256	.13001
30	4.3638	-7.1866	5124.97061	.5484	-1.1812	61.90438	.0884	-.0099	.28908

APPENDIX III
EXPERIMENTAL DIFFRACTION LINE PROFILES

The following instrumental settings were used in obtaining all of the diffraction line profiles. The abscissa is in degrees 2θ .

Cu K α radiation, 50 KV, 40 ma, Ni filter

Scan Speed $\frac{1}{8}^\circ$ /minute, Chart Speed 30"/hour

Time Constant 2 seconds, Scale 64 x .6

Angular Aperture 1° , Receiving Slit 0.003"

Xenon Proportional Counter, 1725 volts

Base 7 volts, Window 3 volts

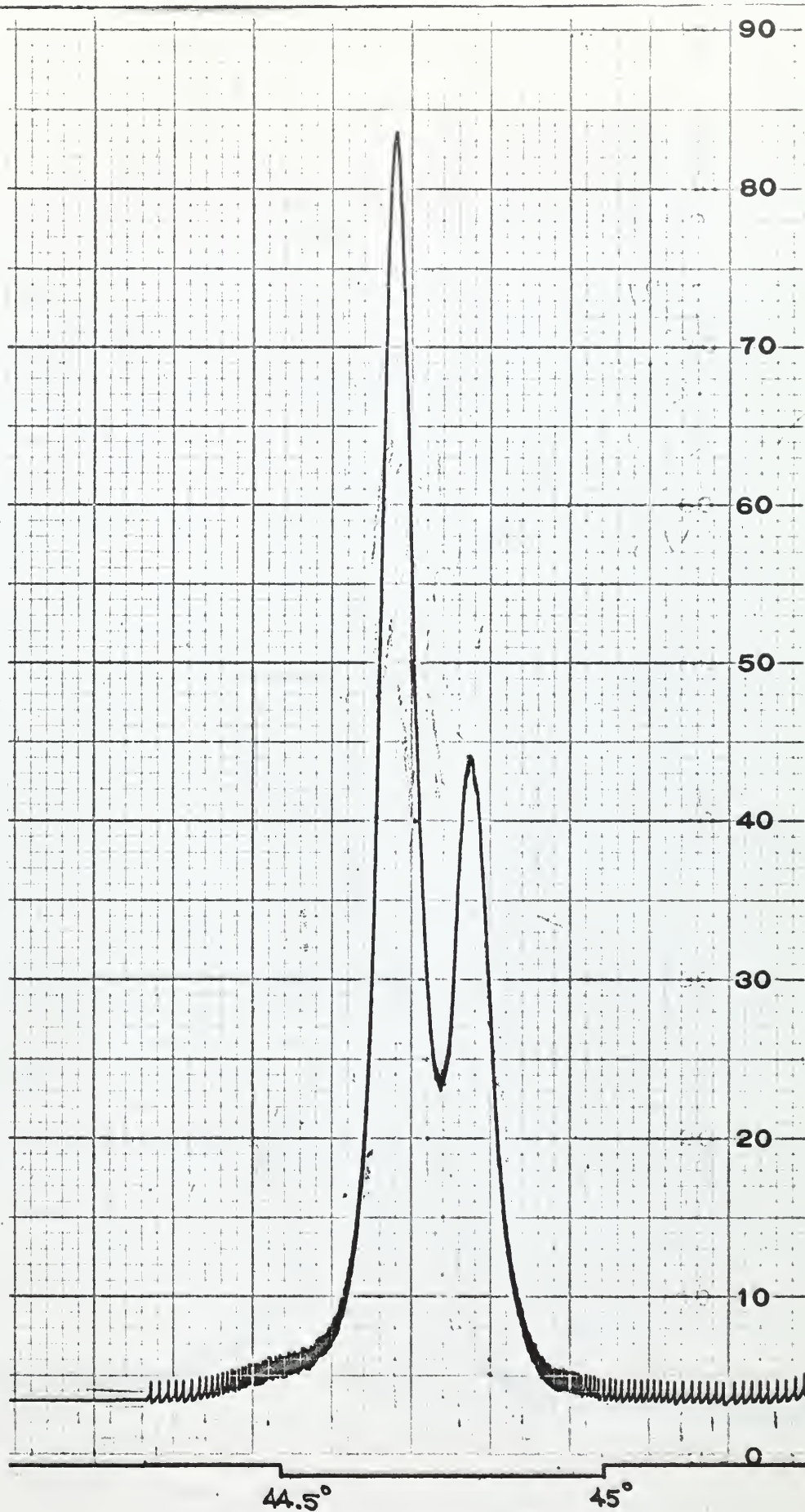


Fig. 20. Reference Peak,
Pure Aluminum

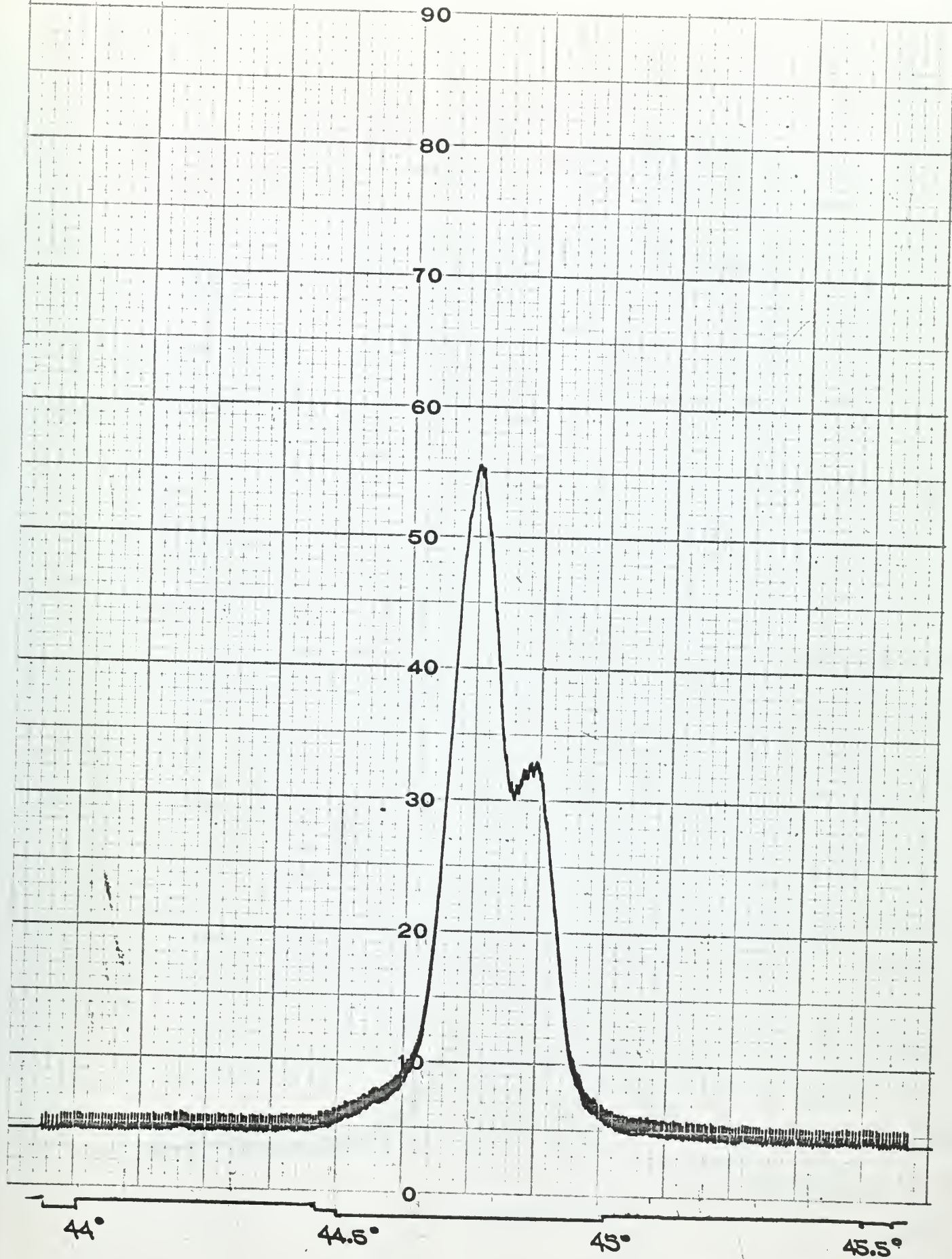


Fig. 21. As Quenched

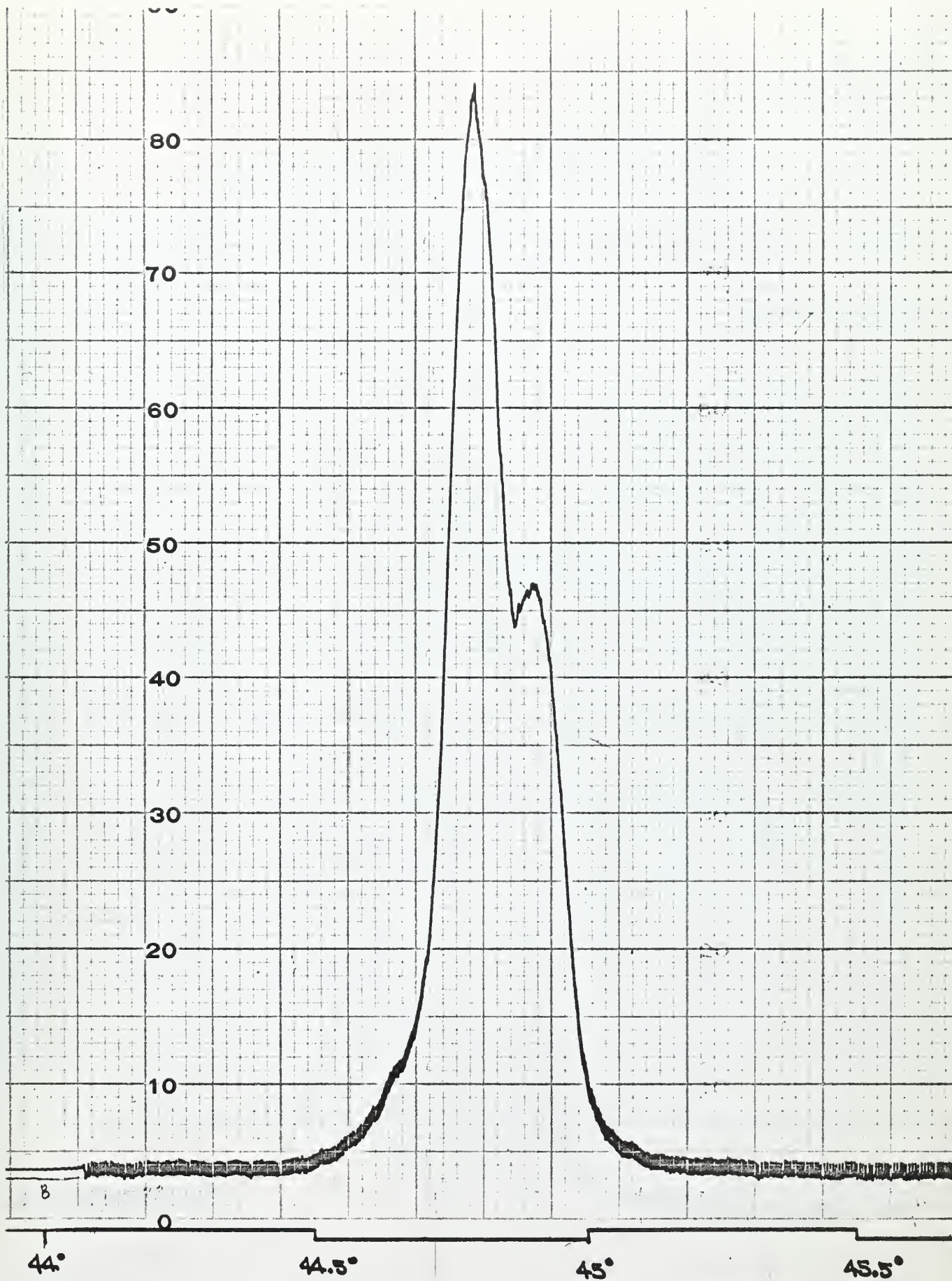


Fig. 22. Aged 65 days, Room Temp.

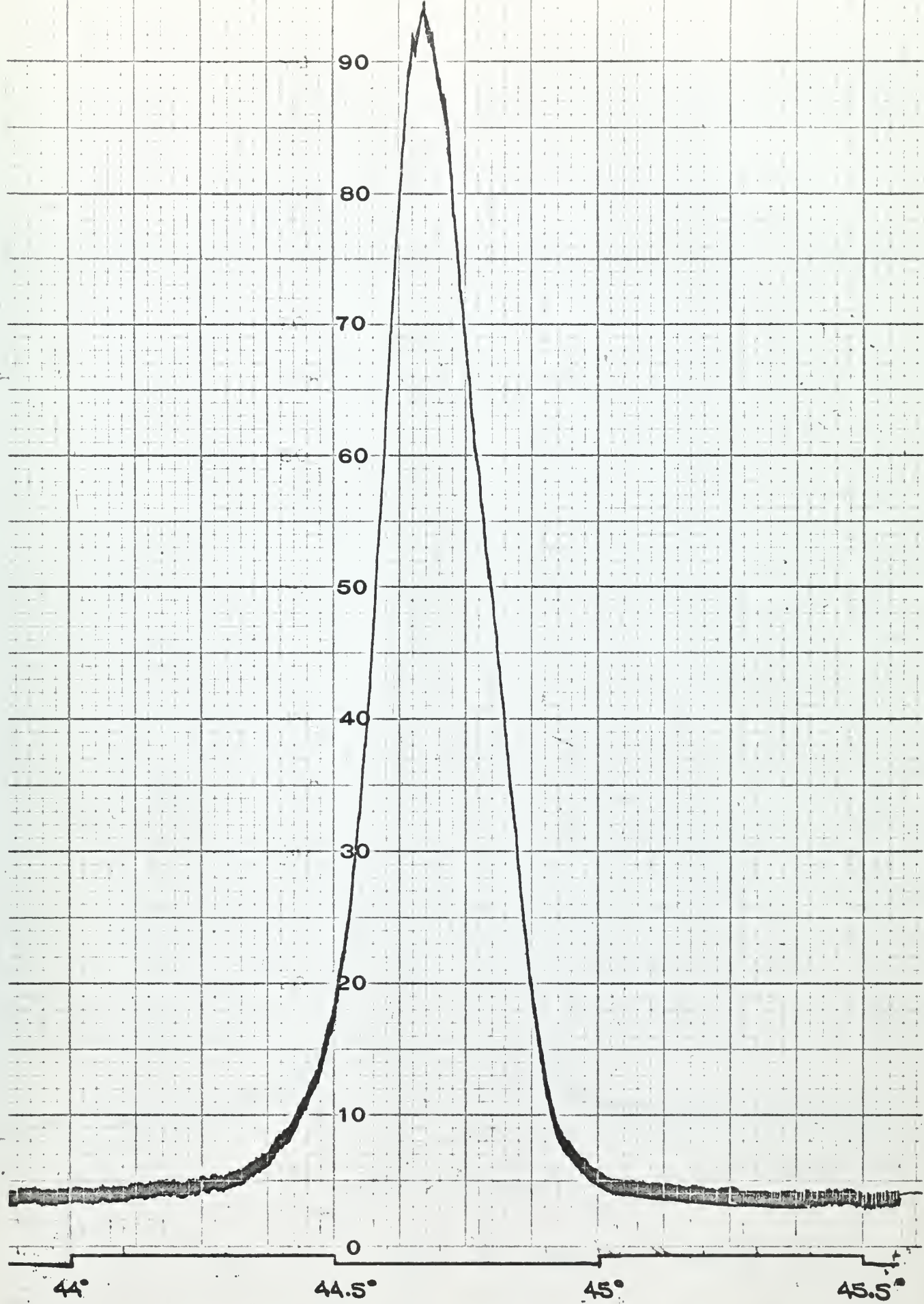


Fig. 23. Aged 1 day at 165°C

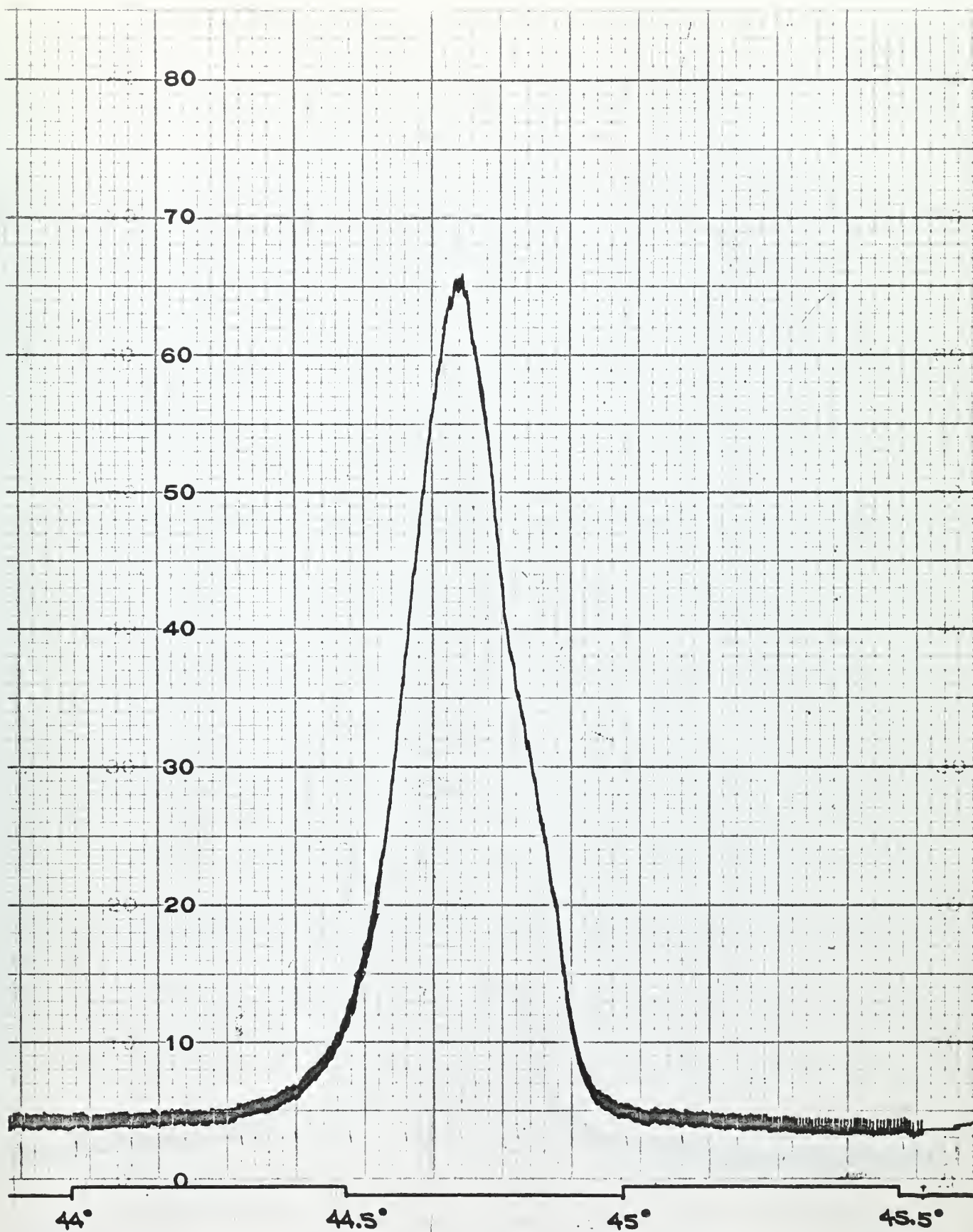


Fig. 24. Aged 2 days at 165°C

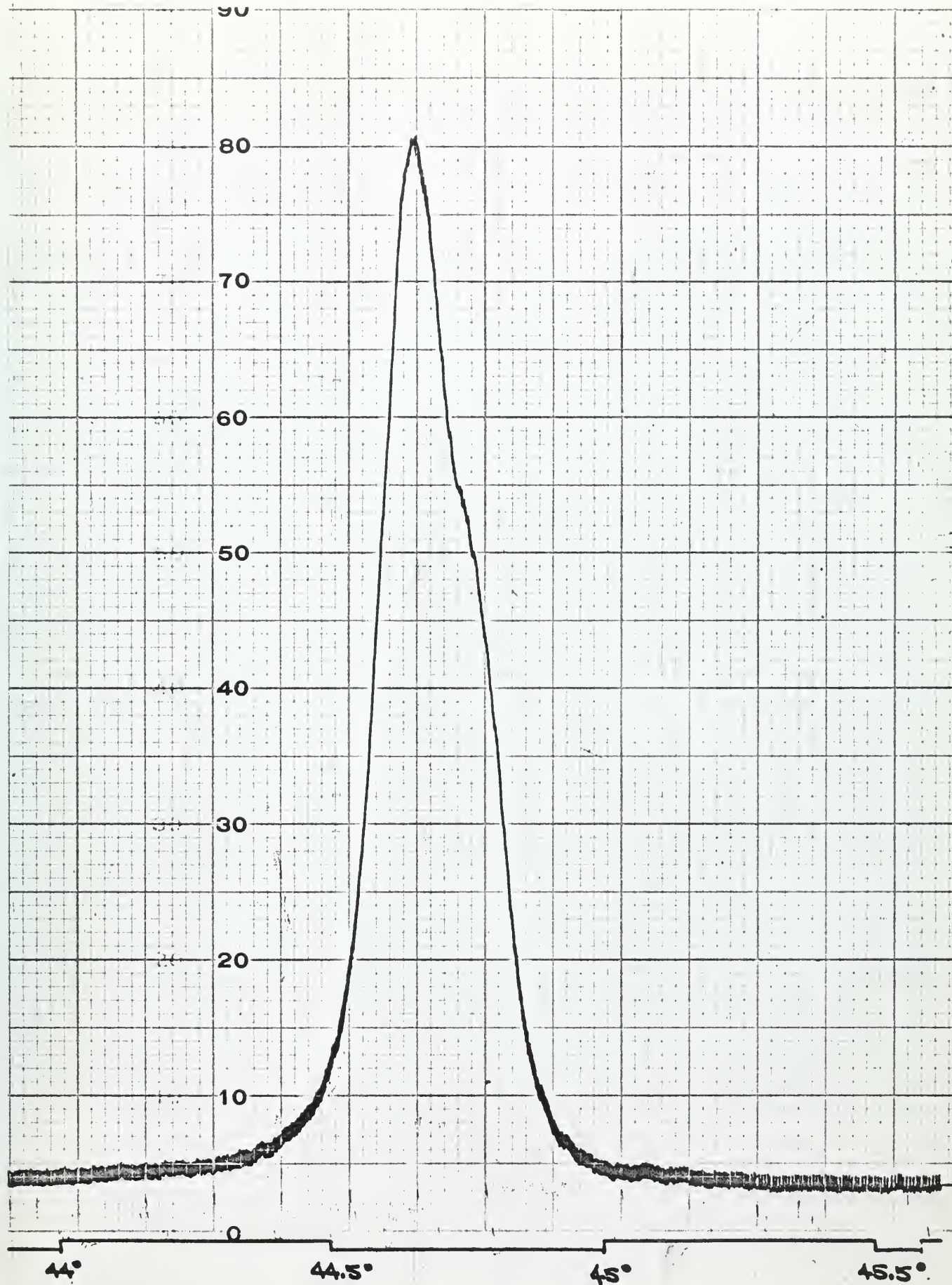


Fig. 25. Aged 5 days at 165°C

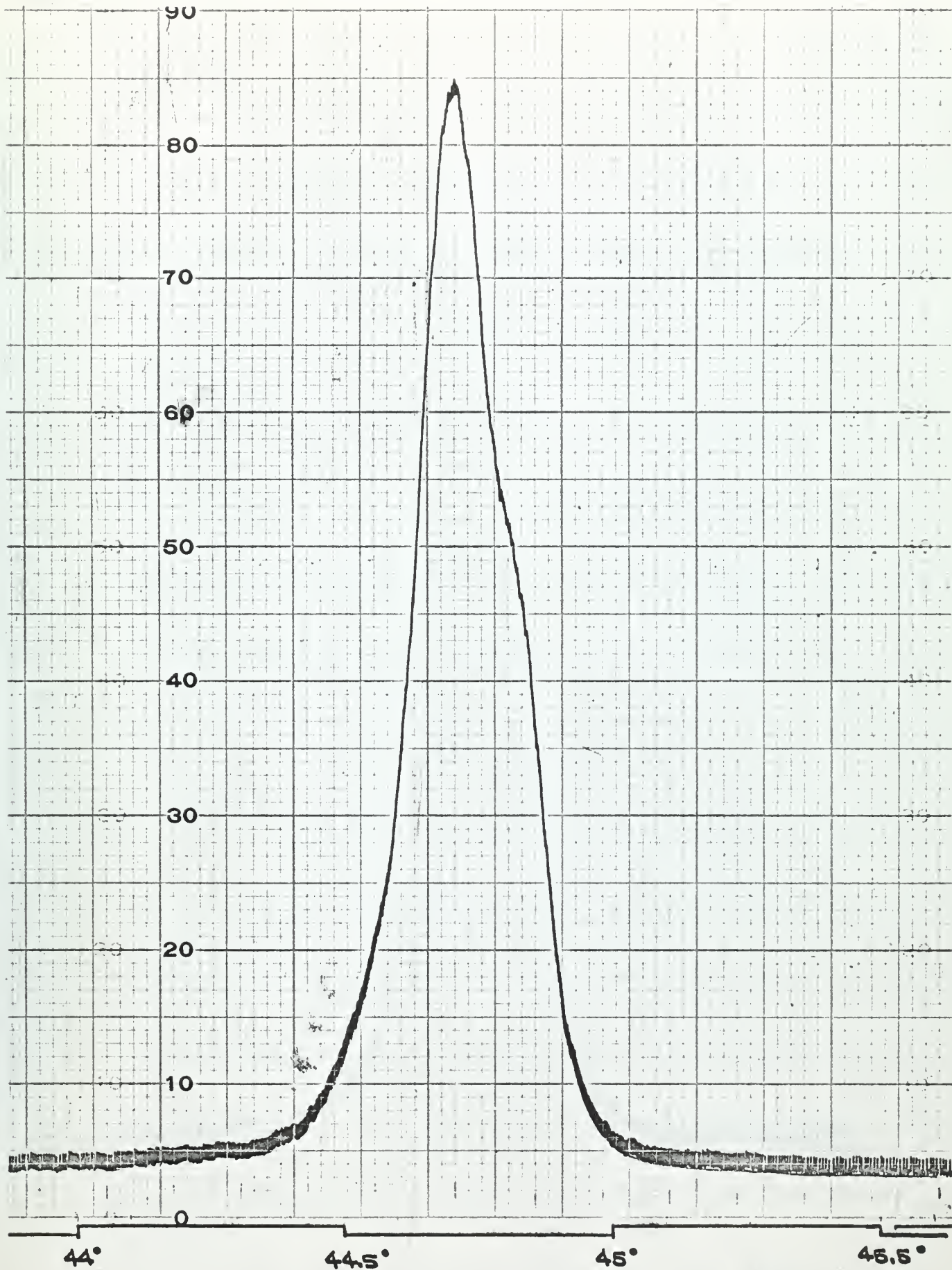


Fig. 26. Aged 9 days at 163°C

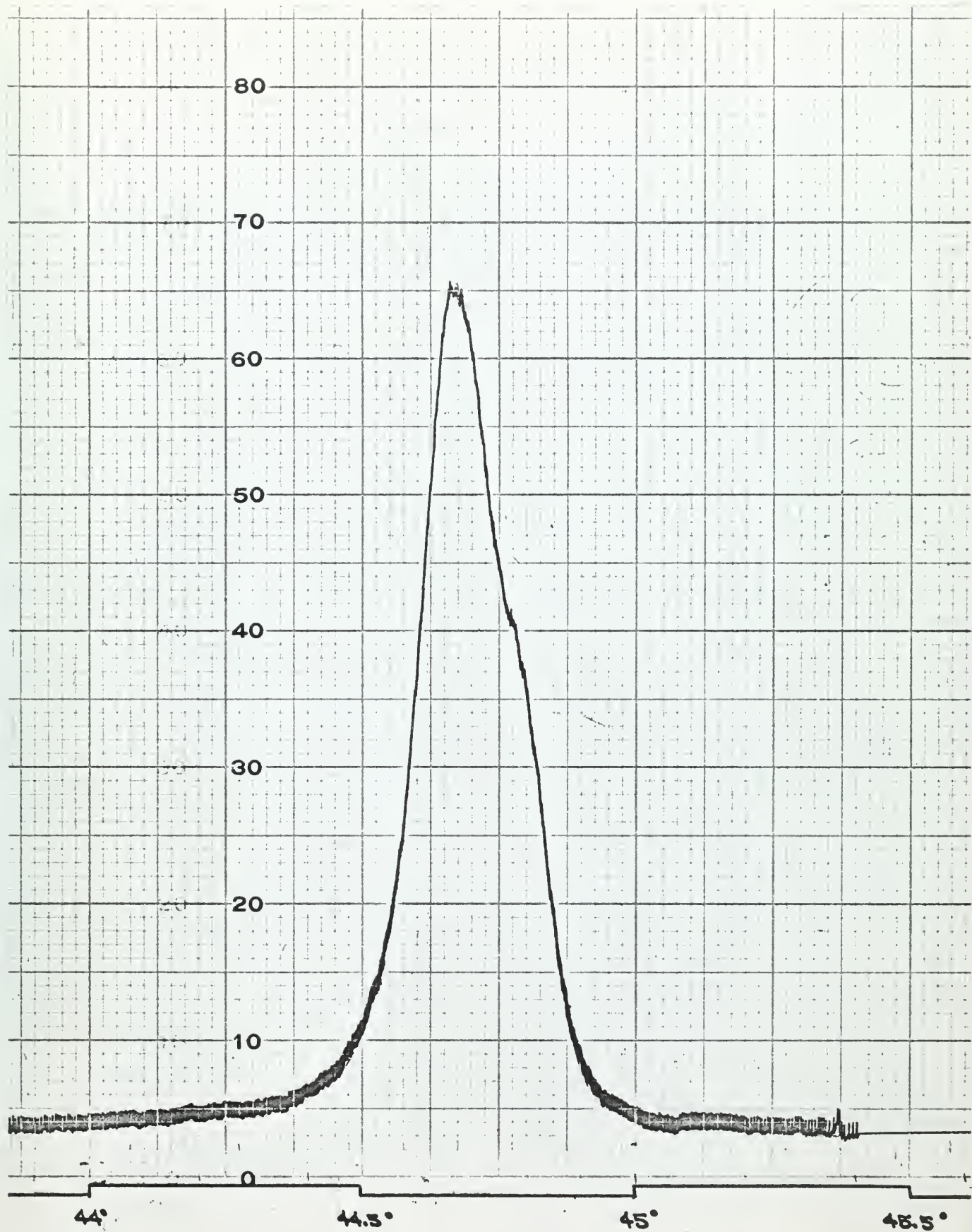


Fig. 27. Aged 14 days at 165°C

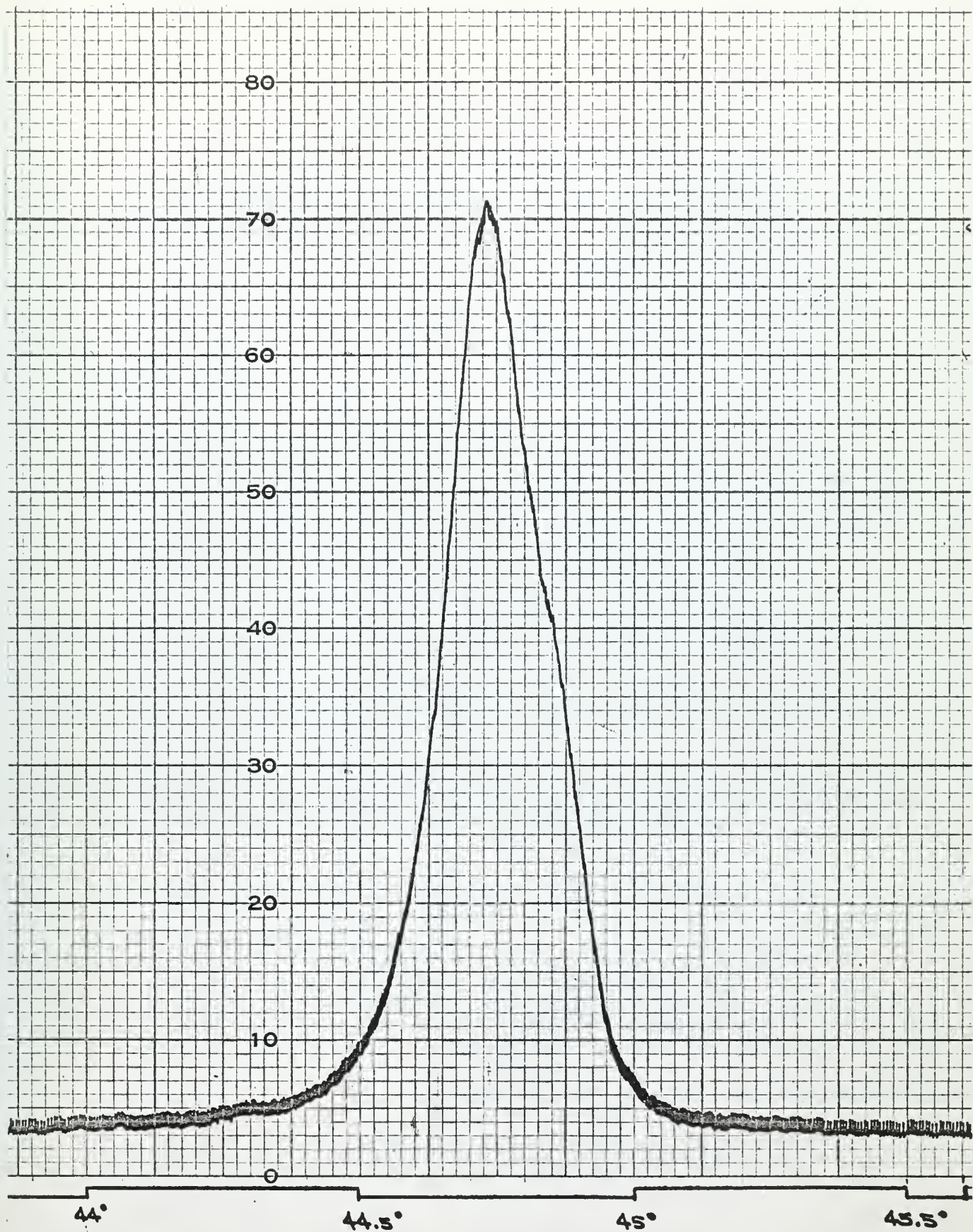


Fig. 28. Aged 30 days at 165° C

APPENDIX IV

THE FOLLOWING IS A FORTRAN 60 COMPUTER PROGRAM
THAT WILL PERFORM THE STOKES UNFOLDING AND PATTERSON
FUNCTION SYNTHESIS.

PROGRAM UNFOLD

THIS PROGRAM WILL COMPUTE

1. THE FOURIER COEFFICIENTS $A(N,1)$ AND $B(N,1)$ OF A CURVE
 2. THE FOURIER COEFFICIENTS $A(N,2)$ AND $B(N,2)$ OF A SECOND CURVE
 3. THE FOURIER COEFFICIENTS $A(N)$ AND $B(N)$ OF THE UNFOLDED CURVE 2/1
 4. THE INVERSE FOURIER TRANSFORM (SYNTHESIS) OF THE UNFOLDED CURVE
 5. THE CENTER OF GRAVITY OF THE UNFOLDED CURVE
 6. THE LOCATION OF THE MAXIMUM IN THE UNFOLDED CURVE
 7. A SERIES OF CURVES CAN BE SUCCESSIVELY UNFOLDED
- THE RESULTS CAN BE PRESENTED IN BOTH TABULAR AND GRAPHICAL FORM
GIVEN THE COEFFICIENTS $I(F,(H,K,L))^{**2}$, THE PROGRAM COMPUTES THE
PATTERSON FUNCTION, $Y(U,V,W)$ (I.E. THE SUMMATION OVER THE COSINE
TERMS OF A FOURIER TRANSFORM OF $I(F,(H,K,L))^{**2}$).
THE RESULTS ARE PRESENTED AS ONE OR TWO DIMENSIONAL SECTIONS
ONE DIMENSIONAL SECTIONS CAN BE PRESENTED IN BOTH GRAPHICAL AND
TABULAR FORM
TWO DIMENSIONAL SECTIONS ARE PRESENTED IN TABULAR FORM
THE EXPERIMENTAL VALUES, $I(F,(H,K,L))^{**2}$ ARE CORRECTED FOR LORENTZ,
POLARIZATION, MULTIPLICITY AND TEMPERATURE FACTORS

FIRST DATA CARD CARRIES GENERAL TITLE - COLUMNS 2 - 80

SECOND DATA CARD

- COL 1-3 NA = 1 FOR THE FIRST CURVE OF A SET
 = 2 FOR THE SECOND CURVE OF A SET
COL 4-5 NB = 0 IF FOLDING IS TO BE CALCULATED
 = 1 TO COMPUTE FOURIER COEFFICIENTS ONLY
 A VALUE FOR NB MUST BE ENTERED OR STOP 15
 WILL RESULT.
 DIMENSIONS OF AA, BB, AND FIX DEPEND ON
 VALUE OF NA SPECIFIED
COL 6-7 NC = +1 SYNTHESIS OF UNFOLDED DATA
 = -1 SYNTHESIS OF NEW DATA

COL 8-9 ND = 0 NO GRAPH OF PATTERSON FN.
= 1 GRAPH PATTERSON FN. SEE BELOW.
COL 10-74 TITLE OF UNBROADENED CURVE

THIRD DATA CARD - CONSTANTS FOR ANALYSIS OF UNBROADENED CURVE

COL 1 - 5 N = NO OF INTERVALS
6 - 10 NCG = -1 FOURIER SYNTHESIS - GRAPH
= 0 NO SYNTHESIS
= +1 FOURIER SYNTHESIS
11 - 15 MODE = 1 INPUT DATA PRINTED
= 0 INPUT DATA NOT PRINTED
16 - 20 J - FIRST OUTPUT HARMONIC
(NORMALLY = 0)
21 - 25 K - HARMONIC INCREMENT
(NORMALLY = 1)
26 - 30 L - FINAL HARMONIC
31 - 35 K2 - SUB HARMONIC - IF 0, PROGRAM
SETS K2 = 1.
36 - 40 LC = 0 READS DATA CARD
MEMORY
= 1 USES DATA AVAILABLE IN
41 - 50 THO = INITIAL TWO THETA
51 - 60 THF = FINAL TWO THETA
61 - 73 XL = WAVELENGTH

FOURTH DATA CARD - UNBROADENED CURVE, N EQUALLY SPACED POINTS FORMAT (16F5.1), ON THE NECESSARY NUMBER OF CARDS.

REPEAT SEQUENCE WITH A DUPLICATE GENERAL TITLE CARD, A SIXTH CARD SETTING NA = 2 AND CARRYING A TITLE FOR THE BROADENED CURVE, A SEVENTH CARD SETTING THE CONSTANTS FOR ANALYSIS OF THE BROADENED CURVE, AND AN EIGHTH CARD WITH THE N POINTS OF THE BROADENED CURVE.

FOR A GRAPH OF THE PATTERSON FN, FOLLOW THE TWO SETS OF DATA CARDS (FOR THE REFERENCE AND BROADENED CURVES) WITH TWO MORE CARDS. THE FIRST ONE IS BLANK AND THE SECOND ONE SETS NA=NB=NC=0, ND=1.

• FURTHER CONVOLUTIONS CAN BE CARRIED OUT WITH ADDITIONAL SETS OF FOUR DATA CARDS, INCREASING NA BY ONE FOR EACH FOLD UP TO 10.

ADDITIONAL CURVES CAN BE UNFOLDED BY ADDING ADDITIONAL SETS OF DATA CARDS SETTING NA = 1 AND 2 IN THE SECOND AND SIXTH CARDS OF EACH SET

FOR A FOURIER ANALYSIS SET NB = 1 IN COL 5 IN THE SECOND CARD OF A SET OF DATA CARDS

THE PROGRAM IS TERMINATED BY TWO BLANK DATA CARDS

STATEMENT NUMBERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
35	36	37	38	39	40	41	42	43	44	45	46					
	51	52	53													
60	61															
			103	104	105	106	107	108	109							
110	111	112	113	114	115	116	117	118	119							
120	121	122	123	124	125	126	127	128	129							
130	131	132	133	134	135	136	137	138	139							
140	141	142	143	144	145	146	147	148	149							
150	151	152	153	154	155	156	157	158	159							
160	161	162	163	164	165	166	167									
	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	
900	901	902		904		906	907	908	909							
47	48	49	70	170	71	72	73									

```

1 FORMAT (1H1////)
2 FORMAT (80H0
1
24 FORMAT (I5, 2F10.4, F10.5 , 2F10.4 ,F10.5 ,2F10.4, F10.5)
39 FORMAT(I15, 2F15.4, F15.4//)
40 FORMAT(1H013X1HN10X5HALPHA11X4HBETA6X 9HINTENSITY)
900 FORMAT ( I3, 3I2, 8A8)
901 FORMAT(8I5, 3F10.3)
902 FORMAT (16F5.1)
904 FORMAT(3HON=I4, 7H J=I5, 7H K=I5, 7H L=I5,
1 8H K2=I5,7X6HNCG = I3///12H DATA POINTS//)
906 FORMAT (1H0 16X 9HREFERENCE 20X 11HBROADENED 21X 9HCORRECTED //)
907 FORMAT(1H0 4X 1HN 2X 5HALPHA 7X 4HBETA 3X 9HINTENSITY 4X 5HALPHA
1,6X 4HBETA 2X 9HINTENSITY 4X 5HALPHA 6X 4HBETA 2X 9HINTENSITY//)
908 FORMAT(1X)
909 FORMAT(1X, 16F5.1)

```

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DIMENSION Y(200), AA(200,4), BB(200,4), FIX(200,4), NAME(8),
1 FR(200,4), FI(200,4), FIT(200,4),
2 Z(1,1,900)

```



```

DIMENSION  WW(900),  ITITLE(12)
DO 71 I=1, 12
71 ITITLE(I) = 8H
ITITLE(1) = 8H LARSEN
ITITLE(2) = 8H 0278
ITITLE(7) = 8HPATTERSO
ITITLE(8) = 8HN FUNCT
ITITLE(9) = 8HION FOR
ITITLE(10) = 8H AL-CU
LABEL = 4H 65D

C
TPI = 6.28318530718
R=1.0/(57.2957795131*2.0)
3 READ 2
READ 900, NA, NB, NC, ND, NAME
IF(NC) 122, 15, 47
47 IF(NA) 15, 15, 9
15 IF (ND) 48,48,49
49 CALL DRAW(101,Z,WW,0,0,LABEL,ITITLE,0,10.0,0,0,0,0,9,10,1,LAST)
GO TO 3
48 STOP 48
9 READ 901, N, NCG, MODE, J, K, L, K2, LC, TH0, THF, XL
IF(K2) 30,31,30
31 K2 = 1
30 FN = N
TNR = 2./FN
THF = THF*R
TH0 = TH0 * R
C
IF LC EQUALS ZERO, READ NEW DATA, OTHERWISE OPERATE ON OLD
IF (LC) 32,33,32
33 READ 902, (Y(I), I= 1,N )
32 PRINT 1
PRINT 2
PRINT 900, NA, NB, NC, ND, NAME
IF (MODE) 12,13,12
12 PRINT 904, N, J, K, L, K2, NCG
PRINT 909, (Y(I), I = 1,N)
IF (NA - 1) 515, 513, 514
515 STOP 515
513 AREA = 0.0
DO 511 I = 1,N
AREA1 = (Y(I)*(SINF(THF) - SINF(TH0)))/(XL * FN)
511 AREA = AREA + AREA1
514 DO 512 I = 1,N
512 Y(I) = Y(I) / AREA
13 XK2 = K2
XJ = J
ARG = TPI/FN/XK2
ARG1 = ARG*XJ

```



```

      CS = COSF(ARG1)
      TCS = 2.*CS
      SS = SINF(ARG1)
      XK = K
      ARG2 = ARG*XK
      CB = COSF(ARG2)
      SB = SINF(ARG2)
      M1=J
      GO TO (501,502,503,504,505,506,507,508,509,510), NA
501  NAN=NA
      GO TO 14
502  NCW=NA
      NAN=NA-1
      GO TO 14
503  NCW=NA-1
      NAN=NA-2
      GO TO 14
504  NCW=NA-2
      NAN=NA-3
      GO TO 14
505  NCW=NA-3
      NAN=NA-4
      GO TO 14
506  NCW=NA-4
      NAN=NA-5
      GO TO 14
507  NCW=NA-5
      NAN=NA-6
      GO TO 14
508  NCW=NA-6
      NAN=NA-7
      GO TO 14
509  NCW=NA-7
      NAN=NA-8
      GO TO 14
510  NCW=NA-8
      NAN=NA-9
C    BEGINNING OF LOOP ON M1
      14  T3 = 0.
          T2 = 0.
          I = N
          18  T1 = TCS. * T2 - T3 + Y(I)
              I = I-1
              IF (I) 16,19,17
          16  STOP 16
          17  T3 = T2
              T2 = T1
              GO TO 18
          19  M=M1+1

```



```

AA(M,NA) = (T1 - CS*T2)*TNR
BB(M,NA) = (SS*T2)*TNR
FIX(M,NA)=(AA(M,NA)*AA(M,NA) + BB(M,NA) * BB(M,NA))/TNR
C TEST FOR END OF M1 SERIES
IF(M1-L) 21,26,20
20 STOP 20
21 M1=M1+K
TCS = CB*CS - SB*SS
SS = CB*SS + SB*CS
CS = TCS
TCS = TCS + CS
GO TO 14
26 NO=NA-1
11 IF(NO) 23,42, 27
23 STOP 23
42 IF(NB) 27,3,27
27 PRINT 1
PRINT 2
L2=L+1
J2=J+1
IF(NB) 37,38,37
37 PRINT 40
PRINT 908
DO 43 M = J2, L2
M2=M-1
43 PRINT 39,M2,AA(M,NA),BB(M,NA),FIX(M,NA)
GO TO 3
38 PRINT 906
PRINT 907
IF(NA-2) 22,22,28
28 AA(M,NAN)=AA(M,NO)
BB(M,NAN)=BB(M,NO)
FIX(M,NAN) = (AA(M,NAN)*AA(M,NAN)+ BB(M,NAN)*BB(M,NAN))/TNR
22 DO 25 M=J2,L2
M2=M-1
J2 = J + 1
FR(M,NO) = (AA(M,NCW)* AA(M,NAN)+ BB(M,NCW)*BB(M,NAN))/FIX(M,NAN)
1 *TNR
FI(M,NO) = (BB(M,NCW)* AA(M,NAN)- AA(M,NCW)* BB(M,NAN))/FIX(M,NAN)
1 *TNR
IF(M -J2)46, 45, 46
45 FA = FR(J2,NO)
46 FR(M,NO) = FR(M,NO)/FA
FI(M,NO) = FI(M,NO)/FA
FIT(M,NO) =(FR(M,NO)*FR(M,NO) + FI(M,NO)* FI(M,NO))/TNR
PRINT 24 ,M2,AA(M,NAN),BB(M,NAN),FIX(M,NAN) , AA(M,NCW), BB(M,NCW
1) , FIX(M,NCW) ,FR (M,NO) , FI(M,NO) ,FIT(M,NO)
IF(XMODF(M ,45))29,35,29
35 PRINT 1

```




```

PRINT 2
PRINT 906
PRINT 907
GO TO 25
29 IF(XMODF(M,5))25,36,25
36 PRINT 908
GO TO 25
25 CONTINUE
IF(NCG) 122, 44, 122

```

PROGRAM FOUSYN

1ST DATA CARD

COL 1-80 TITLE

2ND DATA CARD

COL 1 - 4 DEBYE TEMP. B

B=0.0 IF TEMP. FACTOR IS NOT COMPUTED

5 - 11 LAMBDA

11 - 14 NUMBER OF PEAKS USED

COL 15 - 20 NUMBER OF INTERVALS/CELL IN X DIRECTIONS

21 - 25 NUMBER OF INTERVALS/CELL IN Y DIRECTION

26 - 30 NUMBER OF INTERVALS/CELL IN Z DIRECTION

ADJUST DIMENSION STATEMENT FOR FRACTIONS UVW OF XYZ USED

3RD DATA CARD

COL 1 - 3 MAX VALUE OF U

4 - 6 MAX VALUE OF V

7 - 9 MAX VALUE OF W

10 - 12 MAX VALUE OF H

13 - 15 MAX VALUE OF K

16 - 18 MAX VALUE OF L

19 - 21 MAX VALUE OF U FOR PRINTOUT

21 - 23 MAX VALUE OF V FOR PRINTOUT

24 - 26 MAX VALUE OF W FOR PRINTOUT ACCORDING TO SECTIONS
WANTED

ADJUST DIMENSION STATEMENT FOR MAX VALUES OF HKL USED

4TH DATA CARD

COL 1 - 3 H

4 - 6 K

7 - 9 L

10 - 14 RELATIVE INTENSITY (WITH DECIMAL POINT)

15 - 18 TWO THETA

19 - 20 MULTIPLICITY

C
C
C
C

122 CONTINUE

51 FORMAT (3(3I3, F5.0, F4.0, I2, F5.0))
52 FORMAT(F4.2,F7.5, I4, 3I5)
53 FORMAT (6I3, 3F4.2, 2F10.4)
4 FORMAT (1H0,2X, 1HN, 6X, 22H(U , V , W)9X, 9H Y(U,V,W)
1 //)
5 FORMAT (I5, 6X, F6.4 , 1X, F6.4, 1X, F6.4, 6X, F12.4)
6 FORMAT(50H)
7 FORMAT (1X)
8 FORMAT (1H1/////)
60 FORMAT(21HOCENTER OF GRAVITY = F6.2)
61 FORMAT (55HOMAX HARMONIC USED FOR SYNTHESIS OF CORRECTED CURVE =
1 I3 //)

C
C
C

167 DIMENSION F(1,1,500), TTH(1,1,500), MU(1,1,500), C3(100),
1 S3(100), F1(1,1,500), C1(1), C2(1), S1(1), S2(1)

IF(NC) 129, 166, 128
166 STOP 166
129 READ 6
READ 52,B,XL,NP,NU,NV,NW
READ 53, J1, J2, J3, I1MAX, I2MAX, U3MAX, U1, V1, W1, TTH0, TTHF
GO TO 136
128 NN1 = 0
NN2 = 0
NU = 0
NV = 0
NW = N
J1 = 0
J2 = 0
J3 = 100
J11 = J1 +1
J22 = J2 +1
J33 = J3 +1
M2 = M - 1
I1MAX = 0
I2MAX = 0
I3MAX = M2
U1 = 0.0
V1 = 0.0
W1 = FN
TTH0 = TH0
TTHF = THF
136 I1M = I1MAX + 1
I2M=I2MAX+1


```

      I3M = I3MAX + 1
      TTHD = TTH0 - TTHF
      DO 115 I3=1,I3M
      IS3 = (I3 - 1)*100
      DO 115 I2 = 1, I2M
      IS2 = (I2-1)*10 + IS3
      DO 115 I1=1,I1M
      IS=IS2+I1
      F(IS)=0.0
      F1(IS) = 0.0
      TTH(IS)=0.0
      MU(IS)=0.0
115  Z(IS)=0.0
      IF (NC) 127, 15, 126
126  DO 137 M = 1, L2
      IF (M-1) 159,159,160
159  I4M = 0
160  IF(I4M) 161,161,158
161  F(1, 1, M) = FR(M, NO)
      F1(1, 1, M) = F1(M, NO)
      IF(FR(M, NO) ) 170, 170, 137
170  I4M = M
      GO TO 137
158  F(1, 1, M) = FR(M, NO)
      F1(1, 1, M) = F1(M, NO)
137  CONTINUE
C      FOR TRY = -1.0, Y(U,V,W) IS SYNTHESIZED USING THE FIRST M
C      HARMONICS THAT KEEP Y(U,V,W) POSITIVE.
162  TRY = -1.0
      I3M = I4M - 1
      I5M = I4M - 2
      GO TO 125
C      FOR TRY = 1.0, Y(U,V,W) IS SYNTHESIZED USING ALL L HARMONICS.
163  TRY = 1.0
      I5M = L2 - 1
      I3M = L2
      GO TO 125
127  IF (XMODF(NP, 3))111, 112, 111
112  NP = NP/3
      GO TO 113
111  NP = (NP/3) + 1
113  DO 114 NR = 1, NP
      READ 51, NN1, NN2, NN3, F(IS), TTH(IS), MU(IS), F1(IS)
      IS=NN3*100+NN2*10+NN1+1
      TTH(IS)=TTH(IS)*R
      AAA=SINF(TTH(IS))
      AAA2=AAA**2
      TE=1.0/EXPF(B*AAA2/XL**2)
      ZZ=COSEF(2.0*TTH(IS))

```



```

POL=(1.0+ZZ**2)/AAA2*COSF(TTH(IS))
AMU(IS) = MU(IS)
F1(IS) = F1(IS)/(TE * POL *AMU(IS))
114 F(IS) = F(IS)/(TE * POL *AMU(IS))
125 PRINT 8
    IF (NC) 131, 15, 130
131 PRINT 6
    GO TO 132
130 PRINT 2
    PRINT 61, I5M
132 PRINT 4
    TPI=6.28318530718
    MARK=0
    IF(NC) 157, 138, 139
138 STOP 138
139 JU = 1
    JV = 1
    GO TO 140
157 DO 104 JU = 1, J11
    DO 104 JV = 1, J22
140 DO 104 JW = 1, J33
    IF(NC)153, 154, 155
154 STOP 154
155 U = 0.0
    V = 0.0
    GO TO 156
153 AJU = JU - 1
    ANU = NU
    U = AJU/ANU
    AJV = JV - 1
    ANV = NV
    V = AJV/ANV
156 AJW = JW - 1
    ANW = J3
    W = AJW/ANW
    IF(NC) 141, 142, 143
142 STOP 142
143 I1 = 1
    I2 = 1
    GO TO 144
141 DO 103 I1=1,I1M
    DO 103 I2=1,I2M
144 DO 103 I3=1,I3M
    NN1 = I1 - 1
    NN2 = I2 - 1
    NN3 = I3 - 1
    FN1 = NN1
    FN2 = NN2
    FN3 = NN3

```



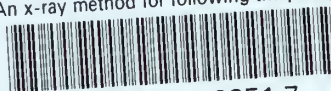
```

      IF (NC) 145, 146, 147
146 STOP 146
147 S1(I1) = 1.0
      S2(I2) = 1.0
      GO TO 148
145 S1(I1) = SIN(F(U*FN1*TPI))
      S2(I2) = SIN(F(V*FN2*TPI))
148 S3(I3) = SIN(F(W*FN3*TPI))
      TS = S1(I1) * S2(I2) * S3(I3) * F1(I1,I2,I3)
      IF (NC) 149, 150, 151
150 STOP 150
151 C1(I1) = 1.0
      C2(I2) = 1.0
      GO TO 152
149 C1(I1) = COS(F(U*FN1*TPI))
      C2(I2) = COS(F(V*FN2*TPI))
152 C3(I3) = COS(F(W*FN3*TPI))
      T = C1(I1) * C2(I2) * C3(I3) * F(I1,I2,I3)
      IF (I3 - 1) 117, 116, 117
116 TSM = 0.0
117 TSM = TSM + T + TS
103 Z(JU,JV,JW) = TSM
107 MARK = MARK + 1
      JJW = JW - 1
      PRINT 5, JJW, U,V,W, Z(JU, JV,JW)
      WW(JW) = JJW
      IF (XMODF (MARK, 35)) 109,108,109
108 IF (NC) 134, 15, 133
134 PRINT 8
      PRINT 6
      GO TO 135
133 PRINT 8
      PRINT 2
135 PRINT 4
      GO TO 165
109 IF (XMODF (MARK , 5)) 165,110,165
110 PRINT 7
165 CONTINUE
104 CONTINUE
      IF (TRY) 72,44,44
44 GO TO 3
72 IF (ND) 163,163,73
73 CALL DRAW(101,Z,WW,0,0,LABEL,ITITLE,0,10.,0,0,0,0,6,10,1,LAST)
      GO TO 163
      END
      END

```


thesL2726

An x-ray method for following the precip



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